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A

TREATISE

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INTERNAL NAVIGATION.

EXPLAINING THE PRINCIPLES BY WHICH CANALS AND THEIR APPENDAGES ARE LAID OUT, CONSTRUCTED AND KEPT IN REPAIR, TOGETHER WITH OTHER INTERESTING AND USEFUL MATTERS CONNECTED WITH THE SUBJECT;

COMPILED FROM THE LATEST AND MOST APPROVED AUTHORITIES:

TO WHICH IS ANNEXED,

THE

REPORT OF ALBERT GALLATIN

ON

ROADS AND CANALS.

BALLSTON SPA:
PRINTED BY U. F. DOUBLEDAY.

1817.

SOUTHERN DISTRICT OF NEW-YORK, SS.

BE it remembered, that on the thirty first day of January, in the forty first year of the Independence of the United States of America, *JOSHUA SECOR*, of the said district, hath deposited in this office the Title of a Book, the right whereof he claims as proprietor, in the words following, to wit:

"A Treaties on Internal Navigation. Explaining the principles by which Canals and their appendages are laid out, constructed and kept in repair; together with other interesting and useful matters connected with the subject: Compiled from the latest and most approved authorities: To which is annexed, the Report of Albert Gallatin on roads and canals."

In conformity to the act of the Congress of the United States, entitled "An Act for the encouragement of Learning, by securing the copies of Maps, Charts, and Books to the authors and proprietors of such copies, during the time therein mentioned." And also to an act, entitled "An Act, supplementary to an Act, entitled an Act for the encouragement of Learning, by securing the copies of Maps, charts, and Books to the authors and proprietors of such copies, during the times therein mentioned, and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

THERON RUDD,
Clerk of the Southern District of New-York.

ERRATA.

Page.	Line.			
4,	3 & 4, *from top*,	*for* countries	*read* counties.
28,	7, - -	tallee	— taller.
33,	10, *from bottom*,	— stone-beach	— stone-brach.
59,	5, *from top*,	— there	— these.
65,	5, *from bottom*,	— here	— hence.
84,	11, *from top*,	— emptying	— empty.
85,	10, *from bottom*,	— level	— bevel.
85,	6, -	— levelled	— bevelled.
88,	*bottom*,	— rock	— rack,
95,	2, *from top*,	— line-fences	— live-fences.
148,	14, *from bottom*,	— water-gates	— waste-gates.

144.——The following paragraph, which ought to have been inserted after the 2d paragraph of that page, was omitted by mistake of the printer:

"A canal 26 feet wide at top, and 10 feet at bottom, and 6 feet deep, will require 12½ acres of land per mile, and will be 12 cubic yards for every yard run, which, if good earth, is a man's day's work, if not wheeled above 10 yards on each side; but if cut deeper or wheeled further, 1½ per yard for 20 yards more.—A canal 5 feet deep should contain 5 feet depth of water.

PREFACE.

THE subject of Internal Navigation by means of canals, has, for some time past, considerably occupied the public attention, not only in the State of New-York, but in various other parts of the United States; but so few, are the works of that kind, which have been executed in this country, that there are many otherwise well informed individuals, who possess very little knowledge of their utility, their construction, or their expense. Nor, is the means of such information, from books, within the reach of the common reader; as the best treatise, it is believed, on the process of canal-making, written by Mr. *Thomas Telford* an eminent English engineer, is contained in *Rees' Cyclopedia*, a very voluminous work, the cost of which is between $200 and $300. These considerations seemed to call for a plain and practical treatise, of trifling expense, from which, information, necessary to induce a correct estimate of this important subject, might be derived. Not only with a desire of effecting this object, but in compliance also, with a request of the board of Canal Commissioners of the State of New-York, has the following compilation been made.

The reader of the following pages will bear in mind, that he is perusing the works of British authors, except where he is informed to the contrary; and if he wishes to learn, with what propriety and fidelity they have been selected, and transcribed, he has only to consult those writers to whose works references are made. The introductory remarks are principally selected from "Inland Navigation" by *J. Phillips*; that part of the work which relates to the process of canal-making is a-

bridged from the treatise of Mr. *Thomas Telford* above mentioned; and the chapters on levelling and water-cements from the appropriate articles in *Rees' Cyclopedia*:—the whole has been divided into chapters, merely for the readers' convenience. It will be perceived, that several other authors than the above are mentioned; and among the rest, that both Mr. *Telford* and Mr. *Phillips* have refered to a work written by our lamented countryman *Robert Fulton, Esqr.*

Mr. *Fulton* went to Great Britain while a mere youth, and shortly thereafter (in 1796) wrote a volume on the subject of Inland Navigation, which is more frequently referred to, and treated with greater respect by the most eminent English engineers, than any other work of the kind. Such was the intuitive rapidity with which his active and comprehensive mind, embraced and elucidated the most complicated subjects! And, in whatever estimation his opinions on the subject of canals, may be held by his countrymen, it ought to be known, in honor to the memory of departed worth, that they are justly appreciated in Europe.

The great value of lands in England, for agricultural purposes, in consequence of the density of population; the numerous parks, pleasure-grounds, fish-ponds, country-seats, and other works of pride and luxury, with which that country abounds; the paucity and smallness of the streams of water, incident to an insular situation, and the occupancy of those streams, not only by the number of mills and other hydraulic machines which such an abundant population requires, but by the numerous canals already in existence;—these artificial obstructions added to the natural unevenness of the ground, which is greatly "variegated with hill and dale," render the business of an English engineer, who has to surmount so many obstacles, in determining on the line of a canal, a most intricate and perplexing science. The laborious process of puddling and lining is adopted, to preserve, if possible, every particle of water from escape; and yet, with all these difficulties and expenses to encounter, so intent are the people of Great Britain

on multiplying canals, after having experienced their beneficial effects, that to accomplish this object, they not only remove hills, tunnel through mountains, and make aerial passages across vallies, on aqueduct bridges, at an elevation of more than one hundred feet in the air; but they also construct them in places where there is a total deficiency of water for lockage: and inclined-planes, and many other expedients are devised and adopted as substitutes for locks.

As the United States, in almost every place that can be selected abounds in copious streams, amply sufficient for all the purposes of artificial navigation, it was deemed unnecessary to swell the following pages with an account of the various substitutes for locks or of railways or tram-roads, a knowledge of the construction of which would probably be uninteresting to the American reader.

On a comparison of the facilities for canal-making in Great Britain and the United States, it is manifest that we possess superior advantages in many respects. Here, it is a simple process, reducible to a few plain rules, not only within the comprehension, but the practical execution of every man of understanding. Here, we have all the materials at a trifling expense; lands are comparatively of little value, and inexhaustible supplies of water may be had for nothing, nor is there here, any "noblemen" or "gentlemen" whose *veto* could prevent a work of public utility from traversing their domains.

The easy transportation of the materials for manufactures is one reason, among others, why the British manufacturer can afford the products of his labor at so small a price; and if the people of the United States, by an unaccountable fatality, I had almost said fatuity, are to permit their manufactories to languish and expire; if they are to continue the mere "growers" of the productions of the earth; if they are destined, in perpetuity, to barter the luxuriant productions of their soil for the gewgaws of Europe, at not only an immense sacrifice, but with a continual balance against

them, still they would find an incalculable advantage in the increased facilities which canals would afford for the transportation of their cumbrous and weighty raw materials.

It cannot escape observation that the price of labor in Great Britain is much less than in the United States, and of course that the excavation of canals will cost more here than in that country; but the cost of excavation in the United States would not, however, exceed that cost in Great Britain in proportion to the excess of the price of labor. In England the earth is removed by manual labor; and it is believed that with us, a plough and scraper, managed by four men, would excavate as many cubic yards of earth in a day, as twenty englishmen with spades and wheelbarrows. But supposing this to be an exaggeration or mistake, a moment's reflection will teach us that the price of labor, whether one shilling or five dollars for a days' work, cannot afford the least objection to the construction of canals; because, whatever may be that price, it is necessarily combined with the transportation of every article of either domestic or foreign consumption.

The farmer, who resides 25, 50 or 100 miles inland, feels the severity of the tax imposed upon him by the price of labor. His salt, his iron, all his groceries, and indeed every article of foreign production comes to him charged with that price of labor which is incident to a tedious and expensive land carriage; while on the other hand, the avails of his own labor, or whatever he has to send to market suffers a proportionate diminution in its value: so that the price of labor whatever it may be, thus necessarily connected with transportation, operates to his disadvantage with a two-fold force; being a continual tax upon every foreign article of his consumption, and an incessant draw-back upon all his surplus productions.

In those countries where labor is cheap, the price of land carriage is proportionably low; and the cheapness of transportation by land, might, with as much force and propriety, have been urged in Great Britain, against the

construction of canals, as the high price of labor in the United States against similar undertakings. We boast of our inventive powers, and pride ourselves upon the discovery and construction of labor-saving machines; and yet we neglect to make canals, on which one day's labor would, at least transport as much as ten on our ordinary roads.

When transportation on canals is contrasted with transportation on British roads and turnpikes, it should be remembered that the roads and turnpikes of that country are very different from ours; that they have been constructed for ages, in no place on an angle of but few degrees of elevation or descent, are besides almost perfectly smooth, and formed of the most compact and imperishable materials. It is however unnecessary to caution the intelligent reader that he is to make an application of the facts and principles contained in the following pages, to the state of his own country, so far as they are applicable, and no further.

The Middlesex canal is the largest work of the kind which has been executed in the United States, and it is presumed that the particulars respecting it which have been transcribed into the following pages will convey some useful information to those who may engage in canal making.

Mr. Gallatin's Report on Roads and Canals contains the best account that has been published, of all the works of that kind, which have either been executed or projected in the Udited States; no apology, therefore, can be necessary for having added it to the volume.

It was the original design of the compiler to have written several notes and illustrations in addition to the very few that are inserted; but on reflection, he deem it more respectful, to permit the intelligent reader, to make his own comments.

Errors and mistakes, in the hurry of transcribing, may have crept into the following work; and any individual by candidly pointing them out, will confer an obligation on the COMPILER.

January 14th, 1817.

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INTRODUCTION.

THAT the greatest advantages are derived by mankind from navigation, which establishes an intercourse between all the different inhabitants of the earth, and enables them to supply their mutual wants; by exchanging their mutual productions, is a position which no one will dispute. To the improvements made in that most useful art, are the commercial nations of Europe principally indebted for their superiority over the rest of the world in power and opulence, the consequence of their extensive trade, and the flourishing state of their manufactures.

But what the ocean is to distant countries which it divides, navigable rivers and canals are to the different provinces and districts of the same country; and as navigation on the former produces an intercourse and mutual exchange of productions between different nations, in like manner inland navigation facilitates a communication between, and consequently promotes trade and industry in the different parts of the same nation. It seems, indeed, almost unnecessary at present, to attempt to enumerate the great benefits that accrue to agriculture, commerce and manufactures from inland navigation. There is scarcely any civilized people, either ancient or modern, but have borne testimony to the utility of canals by executing works of that kind.

If we advert to fact, and consult the records of history with regard to the state of different nations, we shall find, that civilization and commerce have very much depended on the facility with which the inhabitants of remote districts have maintained intercourse with one another, as well as with distant countries. The nations

that appear to have been first civilized, were those that dwelt round the coast of the Mediterranean sea, which, from a variety of circumstances, was extremely favorable to the early navigation of the world. Of all the countries on the coast of the Mediterranean, Egypt seems to have been the first, in which either agriculture or Manufactures were cultivated and improved to any considerable degree. Upper Egypt extends itself no where but a few miles from the Nile, and in lower Egypt that great river breaks itself into many different canals, which, aided by a small degree of art seem to have afforded a communication by water carriage, not only between all the large towns, but between all the considerable villages, and even to many farm-houses in the country; nearly in the same manner as the Rhine and the Maese do in Holland at present. The extent or facility of this inland navigation was probably one of the principal causes of the early improvement of Egypt — The improvement in agriculture and manufactures seems likewise to have been of very great antiquity in the provinces of Bengal in the East Indies, and in some of the eastern provinces of China. In Bengal the Ganges and several other large rivers form a great number of navigable canals, in the same manner as the Nile does in Egypt. The case is the same in the eastern provinces of China, where several large rivers form, by their different branches, a multitude of canals, and by communicating with one another afford an inland navigation much more extensive than that either of the Nile or the Ganges, or perhaps of both of them united. It is remarkable, however, that neither the ancient Egyptians, nor the Indians, nor the Chinese, encouraged foreign commerce; but they all seem to have derived their extraordinary opulence from an internal trade created by this inland navigation. On the other hand, those nations that have been destitute of the means of inland navigation, either by rivers or canals, have remained from one age to another in the same barbarous and uncivilized state. This observation is exemplified in the state of all the inland parts of Africa, and of that

part of Asia which lies at any considerable distance north of the Euxine and Caspian sea, the ancient Scythia, and the modern Tartary and Siberia.

The canal begun by the Duke of Bridgewater in 1759 has so evidently shewn the great advantages to be derived from such works, and given birth to so many similar projects, that since that time no less than 165 acts of Parliament have been passed for making and perfecting canals, or for improving the inland navigation of this country.

Inland navigation is highly beneficial to trade and commerce, by facilitating the communication between widely distant parts of the kingdom, reducing the price of carriage, and thus enabling the manufacturer to obtain his materials, fuel and necessaries of life at a lower rate; to convey his goods to market at a less expense, and consequently to sell cheaper than his competitors. In countries which have the advantage of canals, old manufactories are rendered more flourishing, and new ones established from day to day, in situations where, before, the land was but of little value, and but thinly inhabited. They render the countries through which they pass more rich and fertile; since every meadow and pasture displays a verdure never seen in the withered and adust spots which are at a distance from the banks of rivers and running waters. The merchants who reside at the ports where they terminate must also derive very considerable advantages from them, as they are enabled to export greater quantities of goods from places at a distance from the sea, and to supply with ease a greater extent of inland country with the commodities they import from foreign nations.

There are, perhaps, few objects of internal policy that have so much called forth the powers and resources of the country as canals. They have not only been the means of enlarging our foreign commerce, but of giving birth to an internal trade, which, with all the advantages attendant on foreign commerce, has perhaps far exceeded it in extent, value, and importance. So great has been the effect which these canals, and the trade to

which they have given birth, have had on our industry, population and resources, that in many instances they have entirely changed the appearance of the countries through which they flow.

The reasons of this change are sufficiently obvious. As consumers we are enabled by means of canals to import more cheaply; as producers, we export with greater facility. Do the materials of a manufacture lie dispersed? Canals unite them, and at the same time supply the persons employed in it with every necessary at the cheapest rate; and the land owner, whether we consider the produce of the soil or of the mines beneath it necessarily finds his advantage from new markets, and from having a cheaper carriage both for foreign necessaries and his own productions. The experiment has now been made for some years, and canals have been cut to an extent of above 1000 miles and in most cases to the advantages of the public, even where they have not been profitable to the individuals concerned in them.

To the cheapness of conveyance, compared with land carriage, should be added the advantages attendant on an easy and secure communication of the different parts of the country one with another, during the tempestuous months and in times of war; no lives are lost by navigating the calm surface of a canal; and merchandise may be imported and exported with perfect safety from boisterous weather or obtruding enemies. In short, if the abundance of fresh water rivers and lakes in a country have always been deemed a blessing, by furnishing a cheap and easy mode of intercommunication to its inhabitants, there is no reason for supposing that artificial inland navigation is not in this respect equally beneficial.

There are countries, in particular China and Holland, that have systematically encouraged canals and inland navigations at the public expense, neither of them wanting wealth, population or employment. France has not been deficient in public undertakings of a similar nature. In England the zeal of individuals has had a public sanction; but the undertakings have been con-

ducted at private expense. We build palaces for our public officers, and lavish immense sums in warlike preparations, more frequently actuated by caprice and passion, than guided by our true interests; but we do not sufficiently cultivate those projects which would tend to cherish industry, to produce wealth, and increase real national strength. A time may come when the general system of all governments may be directed more to the encouragement of such public undertakings as may promote population and the real prosperity and happiness of the country, than to the despicable intrigues and destructive ambition of statesmen.

A highway, a bridge, or a canal may in most cases be made and maintained by a small toll upon carriages which make use of them; a harbor, by a moderate port-duty upon the tonnage of shipping which load and unload in it. When the carriages which pass over a highway or a bridge, and the lighters and barges which pass on a navigable canal pay toll in proportion to their weight or tonnage, they pay for maintaining those public works in proportion to the wear and tear which they occasion.

A more equitable way of maintaining such works cannot be found; for the tax or toll, though advanced by the carrier, is finally paid by the consumer, to whom it is charged in the price of his goods. Canals, roads and bridges consequently must be made where there is a trade to support them. In several parts of Europe, the toll or lock-duties of a canal is the property of some private person, whose interest obliges him to keep it in proper repair; if not, the navigation ceases, and with it his profit: his principal as well as his interest is therefore at stake. There is this difference between a highway and a canal, the highway, if neglected, and suffered to fall to decay, is not entirely impassable, whereas a canal is. When a navigable canal has been once made, the management of it becomes quite simple and easy; and with respect to the making, it is reducible to strict rules and method. With proper care and attention its expense may be foretold with as much ac-

curacy as the expense of any work of equal magnitude; it may be contracted for at so much per mile and per lock: such undertakings, therefore, may be, and frequently are, very successfully managed by joint stock companies.

Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of a country more upon a level with those in the neighborhood of large towns; they are on that account the greatest of all improvements. They encourage the cultivation of remote parts, which must always be the most expensive circle of the country, and thereby the value of lands is much improved. They are advantageous to Towns by breaking up the monopoly of the Country in their vicinity; and they are advantageous to all parts of the country; for though they introduce some rival commodities, they open new markets for their produce.

It is not more than 70 years ago that some of the counties in the neighborhood of London petitioned parliament against the extension of turnpike roads into the remoter counties, because those remoter counties, it was pretended, from the cheapness of labor, would be able to sell hay and corn cheaper in the London markets than themselves, and would thereby reduce their rents, or ruin their cultivation. Their rents, however, have risen, and their cultivation has been improved since that time.

All canals may be considered as so many roads of a certain kind, on which one horse will draw as much as thirty horses on ordinary turnpike roads, or on which one man alone will transport as many goods as three men and eighteen horses usually do on common roads. The public would be great gainers were they to lay out on the making every mile of a canal twenty times as much as they expend upon a mile of turnpike road; but a mile of canal is often made at a less expense than the mile of turnpike, consequently there is a great inducement to multiply the number of canals.

The cities, towns, and villages in Holland have such a communication with each other by water, that they appear like streets of the same city in respect to the convenience of carriage; and from every town of any size, at fixed times, passage-boats go from and to the neighboring towns, conveying passengers and goods at cheap rates, and not less certain than our stage coaches. Till these advantages are adopted on our English canals, I shall not consider all the benefits to be received from them, which may be reasonably expected. The cheap and very pleasant conveyance by the Dutch Trackskuyts are mentioned with satisfaction by all travellers in that country; in general the canals of England pass through a country far more pleasant and more varied with hill and dale; the conveyance would be safe, and the voyage, if I may so term it, would, in the summer season, be enchanting, enjoying motion without fatigue, and all the pleasures of travelling at a very small expense.

Bad roads, and a difficulty of communication between places remote from each other, occasion a kind of sterility in a country, and render most things much dearer and scarcer than they would otherwise be; and a nation placed in the most favorable climate, and blessed with the most fertile soil, if it have bad roads and be without the convenient modes of conveyance, will not be so rich and affluent as one less favored in climate and soil, which shall have excellent roads and canals, supposing the genius and industry of both nations to be the same.

Were we to make the supposition of two states, the one having all its cities, towns, and villages upon navigable rivers and canals that have an easy communication with each other, the other possessing only the common conveyance of land carriage, and supposing at the same time both states to be equal as to soil, climate and industry; commodities and manufactures in the former state might be expected 30 per cent. cheaper than in the latter, or in other words, the first state would be a third richer and more affluent than the second. This

perhaps is one of the chief causes of the great wealth of China, which historians tell us is wholly intersected by navigable rivers and canals.

INTERNAL NAVIGATION.

CHAP. I.

QUALIFICATIONS OF AN ENGINEER. EXPLORING AND LAYING OUT A CANAL. ESTIMATE OF EXPENSE.

WHEN it is proposed to form any canal, the choice of a skilful and experienced engineer is an object of primary consideration. Without due attention to this object, many impracticable projects may be adopted and large sums of money may be expended without accomplishing any important and useful purpose. In suggesting the principal qualifications that are necessary for rendering persons competent to be consulted or employed in undertakings of this kind, we shall merely specify some of those that have in an eminent degree distinguished, or that still no less conspicuously distinguish several of our own countrymen. A skilful engineer should undoubtedly possess a considerable degree of mathematical knowledge. Calculations, of which some are of the most abstruse and laborious kind, will frequently occur; and he should therefore, be well acquainted with the principles on which all calculations are founded, and by which they are to be rightly applied in practice. An engineer should also have studied the elements of most or all of the sciences, immediately connected with his profession; and he should particularly excel in an acquaintance with the various branches of mechanics, both theoretical and practical. His knowledge should comprehend whatever has been written or

done by other engineers, and he should have information in every department of his office from an accurate examination of the most considerable works that have been executed in all the various circumstances that are likely to occur. It is necessary, that he should be a ready and correct, if not a finished, draughtsman. He should also be conversant with the general principles of trade and commerce; with the various operations and improvements in agriculture; with the interests and connection of the different owners and occupiers of land, houses, mills, &c.; and with all the general laws and decisions of courts, pertaining to the objects connected with his profession.

By an extensive acquaintance with the disposition, inclination, and thickness of the various strata of matter, which compose the soil or land of the British islands, he will be able to avoid many errors incident to those who are destitute of this knowledge, and to have the course and causes of springs, to which it leads. As the last, though not the least, of these qualifications of an engineer, which we shall enumerate, we shall add, that he should be a man of strict integrity. If, at this day, the affairs of any canal company should be entrusted to a person deficient in all or the greater part of the qualifications above enumerated, the managers of such a company will thus incur a serious responsibility to the proprietors and to the public.

A proper engineer being fixed upon, the adventurers should not tie him down too closely by restrictions as to time, but allow him leisure to consider, digest, and revise again and again, the different projects and ways, which will naturally in most instances present themselves to him in an extensive and thorough investigation. The engineer should be allowed to chuse and employ the most competent assistants, and to call in and occasionally to consult the opinions of eminent or practical men, as land surveyors, agents of the neighboring landed property, the principal and most expert commercial men of the district, and who are the best acquainted with its trade and wants, any eminent miners, &c. &c.;

and such men the engineer should be authorised liberally, and at once to remunerate for their services and intelligence.

Previous to the beginning of any minute survey or system of levelling, the engineer ought to visit personally, and endeavor to make a just estimate, and preserve memorandums of all the objects within the district under consideration; as of the trade and importance of all the towns likely to be affected by the undertaking, of all mines of coal, iron, &c. quarries of lime stone, free stone, slate, &c. or the situation where such can be found, of all manufactories of heavy and cumbrous goods, and other extensive works; and generally of every thing likely to furnish tonnage for a canal.

By this time, if the district under consideration be of very considerable length, more than one, and perhaps several, different routes for the proposed canal have presented themselves; and it will be proper, while the engineer's assistants are carrying levels (using good spirit levels with telescopic sights) along each, and making rough sections of the ground, or brook or river along each line, himself to visit and pass along each of these, noting and weighing more particularly the principal difficulties which present themselves in each route, as summits or hills to be passed, or tunnelled through, vallies to be embanked across, with aqueducts over rivers or brooks, the greater or less plentiful supply of water, particularly at the summit levels, and how far the springs and streams of water are at present appropriated or essential to mills or gentlemen's pleasurable purposes, or to irrigation, or the land occupied by parks, turnpike roads, &c. The advantages of each route should also be as carefully noted; as the shortness of distance, connection with great towns, mines and works either on the line or by short and practicable side cuts or branches, the smallest number of locks, bridges, culverts, &c. In weighing all these circumstances, in order to determine on the most advisable line, it should never be lost sight of, that a canal is altogether a mercantile speculation, and cheapness of conveyance is the grand desideratum thereof: where, therefore, but few,

if any, great towns, works, or mines are found upon a proposed line, and the principal object is to form a connection between the canals of a district more fortunately circumstanced in these respects, and the metropolis, or a great town, as in the case of the *Grand Junction* canal lately completed, it is evident, that much ought to be done to obtain the shortest route that is practicable: if, on the contrary, the district under consideration has great towns, mines of coal, or great works distributed about it, some miles in the total distance may be properly allowed, and a more circuitous route adopted, to embrace as many as possible of these objects.

Before determining upon the route of a canal, its connection with the neighboring canals or river navigations should be well considered, and the engineer should inform himself accurately of the quantum of benefit or injury likely to result to each of such existing navigations by the effecting of the new one, or how far their rivalship, or that of any other scheme which may at the time be in agitation, is likely to affect the one he is employed upon; in all the practicable routes, which present themselves for the new canal.

The most eligible route for the canal being settled in the engineer's mind, he will then proceed to make a rough calculation of the quantity of goods of each different kind, which may be expected to pass upon the line in a given time; he will also examine all the canals and rivers which the proposed canal is to connect with, and ascertain the widths and depths thereof, the sizes of their locks, and of the vessels usually navigating them.

In the particular survey of the line proposed, all the knowledge of the most expert and competent engineers, with the most able assistants, will be requisite. The rough section of the proposed line, before taken, will enable the engineer to see the places of the heights and breadths of the various summits, or ranges of high land that are to be passed, and whether any two or more adjacent ones can be connected by a long summit level, without deserting any considerable town or point

of trade, which will diminish the difficulties of supplying the canal with water, as every such junction of summits preserves the water of two lockages, besides presenting so many more points at which the canal can be supplied with water, from springs and rivulets above its level, or where, in less favorable situations, the same can be collected in a lower level to be pumped up. The extremities of the principal summit or summits being thus nearly settled, it will next be inquired, how far it is practicable and advisable to reduce the height of the same by deep-cutting or by tunnelling, or both of them. The advisable height of the summit level of the canal being settled, if water is not in sufficient plenty, a minute survey of both sides of the range, or ridge which is to be passed and of all its connecting heights, for a considerable distance on each side of the line, should be made by tracing the proposed summit-level along the sides of the hills, particularly noting all the springs or rivulets which rise above or across this line; and all such streams of water should be accurately guaged, and the quantity of water which they discharge per day determined; the same should also be done for all the rivulets or small streams that cross the line of the canal throughout its course; and these experiments should be made not only where the streams cross the line, or levels, but at a considerable distance above and also below those points, the particulars of which experiments should be regularly and formally entered in a book, with all the attendant circumstances, and signed by the parties present at the making of them; as the same may prove of the most important use in future, either for detecting any secret leaks of the canal, or feeders by which any of these streams may be increased, or, in case of future claims being made for the water or the diminution thereof by mill-owners or others, the company may be prepared, either to make a just retribution, or to resist ill-founded or ignorant claims with effect. For calculating the quantity of water discharged through guages or apertures of different kinds and dimensions, theorems should be used which make the necessary al-

lowance (deduced from experiment) for the form of the channels or apertures; such will be found in Dr. *Young's* abstract of M. *Eytelwein's* learned German work on Hydraulics, printed in the Journals of the Royal Institution, as also in *Nicholson's Journal*, 8 vo. iii. 25. The survey of the summit of which we were speaking, ought to be accompanied by a plan, on which should be laid down the exact course of every valley and range of hill above the level of the proposed summit, with every particular of the nature of the soil in each; that in case reservoirs therein should be found necessary to collect rain or spring water, the necessary extent and probable supply of such can readily be determined at a subsequent period. From one end of the proposed summit-level it will be right now to proceed with the survey, tracing the level accurately, and marking the same by pegs or stakes, that will last for some time, and be known by the surveyor, who is to follow and make a plan of the line; the levels being frequently transferred to what are called bench marks, upon the trunk of a tree, a large post or building, the same being noted so particularly in the field or survey-book, that they may be readily found for years afterwards. We suppose the engineers, by this time to have settled the rise that each lock shall have, according to the dimensions adopted for the canal, the probable supply of water on the summit, and other circumstances; the summit-level will be traced as above, till the proper place occurs for making a fall of two or more locks, at about one hundred yards or a little more from each other; and the places of these falls being marked, the level is again to be pursued and traced from the bottom of them, and marked out as before, till the opportunity occurs for another pair or more of locks, or till some obstacle, as a gentleman's park, houses, gardens, orchards, mills, roads, &c. present themselves at a distance, when it will be proper, after referring the level arrived at, to a proper and permanent mark, to proceed forwards, and to examine and well consider the different ways and levels, if more than one of such present themselves by which the ob-

stacle can be passed. From the most confined part of the course for the canal, owing to the obstacle, it will be right to level back, till the former work is met, and in many instances considerably overlapped, in order to determine the most eligible mode of bringing the two levels together, upon the principles before stated, if they can be applied, either by adding another lock, or taking one from any of the sets of them which had been before marked out, as occasion may require, and marking out the new levels thereby occasioned : the line between the summit and the first obstacle, or confined part of the course, being thus adjusted, a new point of departure is to be taken from such obstacle, and the level pursued as before, till the fall for a pair or more of locks can be gained, at the proper distance from each other. It is probable that but few sets of locks can thus be determined upon before some new, and perhaps more formidable obstacle will present itself, which it will be necessary to break off for, and proceed forwards to consider, and to obviate as before ; or the new difficulty may consist of some considerable lateral valley coming into the one which we are supposed to be pursuing, which may occasion an insurmountable or unadvisable length of embankment and aqueducts necessary in order to pass it ; or some gentleman's seat, mill or town, may be found so completely occupying the side of the valley down which the line was proceeding, that the engineer may find it necessary to go back and revise a great deal of what he had done, perhaps quite up to the summit, and perhaps to take a new course down the other, or opposite side of the valley, or at least to determine where, with the least expense of embankment and aqueducts, the valley can be crossed to gain the opposite side. The places of the different sets of locks, or of single ones, if they cannot be avoided, and the line between each being adjusted anew, we will suppose the work again to proceed, till some new obstacle presents itself ; this may be either a total change in the course of the valley that the line was pursuing, so as to render it necessary to begin to mount some oth-

er valley toward a new summit; or some gentleman's park, who is adverse to the measure, may so completely occupy the valley, down which the engineer is intent still upon pursuing his course, that it may be necessary to search out for the most eligible place for tunnelling through the hill into some adjacent valley, which is about to fall into the main valley.

It may happen, in case of a change of the direction of the valley, rendering it necessary to leave it, that some other valley, may be at no great distance, into which the canal must be conveyed by a tunnel; and in in order to render this practicable, it may be necessary to go back, and conduct a good deal of the line that had been done upon a new and much higher level, by omitting some of the locks, in order that the level may be conducted through, and supply the proposed tunnel: in accomplishing this, the former obstacles may occur again, or new and more formidable ones may be presented. In this way, the patience, perseverance and abilities of the engineer must be exercised, until a practicable line of some length is obtained, and staked out; when the assistant land surveyor must follow, and make a correct and particular plan of the line of the several proposed locks, embankments, tunnels, &c. upon the same, and of the several fields or pieces of land through which it passes, or that come within 100 or 150 yards of it in any part. It will likewise be the business of the surveyor to ascertain, with the utmost care, the boundary of every parish and township, what county each is in, the proper names of the owners and occupiers of every piece of land in each, however small, upon or within that distance of the line, with reference to the same upon his plan; and to describe correctly all public and private roads and paths that cross or intersect the line, and to and from what places they lead; the course of all brooks or streams of water, and particularly such as lead to, and contribute to the supply of any mill: the situation of the houses and towns upon the line, or within some miles of it, should also be determined; the nearer they are the greater accuracy will be necessary.

We will now suppose the engineer proceeding with the line, from the end of a tunnel into a new valley, the course of which downwards is in the proper direction; the same process is to be repeated as was pursued in descending from the first summit, until this new valley changes its direction, or until some great town or work has been reached, and it becomes necessary to change the course of the canal, and begin to ascend some new valley or plain towards a new summit, or towards some mine or work at which the canal is to terminate: to the new summit it will be necessary to proceed, and after settling the height of the summit-level, and taking all the preparatory steps for ascertaining the supply of water, and other circumstances of this summit, as described respecting the first, the levels will be traced from this summit downwards, working backwards or up again, as often as obstacles may render it necessary, until the former work in the valley is met, and a proper junction of them contrived: the whole of this part being adjusted, the surveyor may proceed as before with his plan and particulars: while we suppose the engineer returned to the first summit, and from which he will conduct his line and avoid the obstacles thereon in the best way that his ingenuity can suggest, until he arrives at the navigation or sea-port at which his canal is to terminate, and where basons or docks more or less capacious, according to the expected trade, and wharves, cranes and other conveniences may want planning for the accommodation of the traders and the public; all which the surveyor will proceed to survey and plan as before mentioned. It may be necessary to remark, that every town, mine, or work, which happens to lie higher than the line, and to which a collateral cut is to be carried, must be considered as a separate summit, and provision for supplying the lockage thereof must be made, and such of the examination before described gone into as may appear necessary; such towns, &c. as lie below the line and are to have cuts or branches to them, will require water to be let down out of the line to supply their lockage; on which accounts, it is highly desira-

ble, whenever the same is practicable, to conduct the line upon such a level, that the collateral cuts may be upon the same level, by which the trade thereon is much facilitated, and less water required.

A complete plan of the line, and all the projected collateral cuts, feeders, reservoirs, &c. being finished, the engineer will enter on a most careful revisal of the whole scheme, with his plan in his hand; on which all the places where culverts or drains will be required, are to be marked, as also the proper places for the bridges, and the necessary alterations of the roads and paths, which will be cut off by the canal, so that the public may not be incommoded and turned long distances round about, and still, that as few bridges as possible, and those in the least expensive places, may be erected. In some instances new channels will require to be cut for brooks and water-courses, to a considerable extent, in order to save culverts, or bring them to the most desirable spots. For proper security against accidental errors, the whole of the levelling should now be gone over again, and the several bench-marks compared, and renewed with the utmost care by the engineer's assistants, while he is proceeding with the necessary inquiries and calculations, for an estimate of the whole expense of the undertaking.

In a great number of instances, it will be found, that the supplying a canal with water, occasions no inconsiderable share of the whole expense, either in the first cost of mills or streams of water, in land for, and labor in constructing reservoirs, engines to pump up water, &c.; or annually ever afterwards, in the fuel for, and repairing of, engines, hire of water from mills in dry seasons, &c.; this subject should, therefore, employ the most sedulous attention of the engineer, both to make the most economical use of what streams he finds, to procure other supplies of water at the least expense, but above all, to secure an abundant supply.

The dimensions and height of the locks, and breadth of the canal being settled, an accurate calculation made of the quantity of water required to fill a lock; and, with the largest probable number of boats that will pass

in a day, the quantity required daily in every part of the canal; this, with a due allowance for the evaporation, from the surface of the whole canal and its reservoirs, and for the soakage that will take place into the banks, however well they are constructed; will shew the number of locks full of water that will be required, from all the different sources.

We have spoken of the steps proper to be taken for ascertaining the whole supply that can be had above the summit level; and it will often be necessary to make a similar investigation, on points below the level, and to construct reservoirs in such situations, to supply the necessary lockage, for local trade upon the line, near any great town or works, which does not extend to the summit, as also to supply the evaporation and soakage of long lengths, in situations where feeders or springs cannot be taken in by the way; another use of reservoirs in less elevated situations may be, to compensate mills that are lower down the streams for the water that is taken for the use of the canal from the higher branches, or near the sources of such streams.

We shall now return to the revisal of the survey, and making an estimate of the expense of the undertaking on which we supposed our engineer to be employed.—In revising the survey of the line, it may be proper for the engineer to cause holes to be dug at certain distances, as deep as the canal is to be cut, or deeper, to inform himself more perfectly of the soil to be cut in, and the expense attending the same, noting particularly the height to which springs may rise in the several holes.—And here it may be proper to notice a very common error, into which the persons entrusted to execute canals have fallen, in such parts where springs appeared beneath the surface in the cutting, by concluding that the canal would make water, as they term it, in such parts, and that puddling was unnecessary; but where too often it has afterwards happened, that such springs, from having a variety of other vents or outlets, at or very near to the same level, and were, therefore, incapable of being dammed or raised much higher than they then appear-

ed; when the canal has come to be filled with water to a higher level, the course of such springs has been reversed, and the porous strata through which they passed have served to absorb and discharge the water at other places, to a very fatal extent. Land-springs, or such as run only in winter, have generally the same effect, and in summer as copiously take in water, when their own source fails, as they before discharged it. The difficulty of puddling or lining out springs, on account of the powerful effort they make to force their way through the lining, as long as the canal remains empty at first of water, will induce a careful engineer, to endeavor to avoid, if practicable, all springs that will not at all times rise to a higner level than the water is to stand in his canal. It will be part of the business of this revisal of the line, to examine what can be done to straighten the canal, we mean as to sudden bends, by small lengths of deep cutting, and others of embankment, to correct the plan accordingly, and to estimate the extra expense of all such works. The lengths and solid contents of the several embankments in cubic yards or feet, and the distance from which the stuff or soil must be fetched for the same; the lengths and dimensions in like manner of all the deep cuttings, and the distance to which the stuff must be removed; the lengths of the tunnels, the number and depths of the several shafts or tunnel-pits that will be necessary; the lengths of headings or soughs that will be wanted to drain the tunnelling works, these, and all the great variety of other works, as locks, culverts, aqueducts, towingpaths, bridges, reservoirs, &c. &c. some of which we have already mentioned, and others that we shall mention hereafter, ought to be particularly stated, and prices affixed to each species of work and kind of material; and these prices ought by no means to be below the current prices of the best articles of the kind at the time, but due allowance should also be made for the advance of prices, which will take place during the execution of the work. The total probable expense, with a due allowance for contingencies, being thus obtained, the engineer will prepare his general

report and estimate, to be laid, with the plan, before his employers.

The next step in the progress of this business, is an application to the legislature for an act, containing all the clauses applicable to that particular case, empowering the parties concerned to complete their undertaking.

CHAP. II.

ORGANIZATION OF THE COMPANY. APPOINTMENT OF AGENTS, AND OF A RESIDENT ENGINEER. RE-EXAMINATION OF THE LINE, AND STAKING OUT THE SAME. LEVEL-CUTTING, DEEP-CUTTING AND EMBANKMENTS CONSIDERED. SLOPE-HOLES AND LOCK-SPIT EXPLAINED. RULES TO BE OBSERVED WITH RESPECT TO VARIOUS INCLINATIONS OF THE SURFACE OF THE GROUND. PREPARATIONS FOR EXCAVATION.

WE are now to suppose that the act of Incorporation has passed, that the adventurers are organized and that a committee is appointed to superintend the execution of the work and the concerns of the company.

It will not often happen that the engineer can be spared from the prejection and superintendance of other great concerns, to attend to the cutting of the canal and erection of the several works, without the assistance of a *resident engineer*, or more than one, if the line be of considerable length, and distant parts of it are intended to be proceeded with at the same time; and the committee will do well to leave it to their engineer to recommend all such assistant or resident engineers from among those who have been brought up or employed under him, or are well known and approved by him, for their mathematical knowledge and practical skill, experience and attention in the several kinds of works that

are to be executed. The attention of the committee should be directed to the fixing upon some *land surveyor and valuer* of respectability and great practical knowledge, who has been used to and acquired address in the negociation and settlement of purchases and exchanges of property of different kinds; and if he has before been employed upon canals he will be so much the more fit. It may be well also for the committee to consider whether any *local committees* or a *select committee*, may be necessary, to pay the more minute attention to, and to bring before them, the concerns of particular districts of the canal, and to serve other purposes.

The engineer being now informed of the exact bounds within which the law has confined his operations, and of the several restrictions or alterations that may have been imposed or made since his former surveys, will, in all probability, find it necessary to look over the line and all the proposed works again, accompanied by the intended resident engineers; and, in such revisal, it will be proper to divide the line of the canal, and the several works thereof, into the necessary number of parts, and to give concise and definite names to each, which names are to be used in future, in contracts and bills, &c. of which distinct parts or divisions a separate account of the expenses should be strictly kept by the resident engineer, the *overseers*, or counters as they are generally called, (whom the engineer is also to recommend or employ upon the works) and by the office-clerks in a ledger, with proper heads for each length of canal, set of locks, tunnel, embankment, deep-cutting, reservoir, aqueduct or other great work, that may form a separate division; such particular and divided accounts of the works will prove of the most essential service to the committee, and to all others concerned, by informing and maturing their judgment on the actual or probable expense of every different kind of work; and will enable the committee to account to the proprietors how great, and sometimes unavoidable, as well as unexpected, expenses may be incurred.

The committee should now well consider and enquire, whether any part of the line can be completed and opened to advantage, before the whole length can be got ready: and this being determined upon, the engineer should compare and consider, from the estimates and particulars that he possesses, the comparative length of time that every particular work upon the length intended to be first completed will require; and in this order, or with a proportionate exertion and number of men, should the several works be entered upon. Immediately after the plan has been settled, preparations should be made for providing all necessary utensils and implements.

The tunnels, deep-cuttings, embankments, or other great works that are first to be begun, (and the levels, widths, &c. of which we suppose to be completely settled) should be now marked upon the ground, with the necessary allowance of width for the slopes, and the spoil-banks, which the engineer may judge right to remain the permanent property of the company.

The land surveyor will now proceed under the direction of the committee and engineer, to make purchases and procure good titles for all the lands that may be wanted, and to make accurate maps and plans of the same.

The ground for the necessary reservoirs, to supply the part of the line that is to be begun ought to be among the first that is marked out, including space for the head or new embankment that is to be made, and should be treated for and purchased by the surveyor, and conveyed as above mentioned. The ground whereon the locks are to be built, or any wharfs or walled basons are to be made, should also be carefully ascertained by the engineer, and purchased in an early stage of the business, in order that the summer season may be fully embraced, for the building of all the masonry and brick work.

It has been found, by long experience, that the banks of canals against which the water is to lie, ought, in ordinary soils or earth, to have their slopes so apportioned, that one foot in depth will give a horizontal base of one and a half foot; and to these, or some proportions

near them, rather above than below, (as slopes of one and a half to one are in general too small) will the width at top and bottom, and the depth of the intended canal probably be fixed by the engineer. It has also, by experience, been found convenient and proper to make up the banks of canals one foot higher than the water is to stand in them.

We are now to suppose the resident engineer to be proceeding with the setting out of the canal, being furnished with a map of the several fields through which it is to pass, the line that is provisionally settled for its course, but with liberty to deviate within certain limits therefrom, and with bench-marks which the engineer has left and described at certain distances, to regulate the top water level, or height of the water in the intended canal; and, as above observed, one foot higher will be the level of the top-bank, or height of the banks.

It will be proper for this engineer, and we shall in future, for the sake of distinction, denominate the other the *principal engineer*, to trace the levels accurately of each pound or level reach of the canal, and to put in level-pegs or small stakes, at every two or three chains, more or less according as the ground is more or less undulating, as he proceeds; wherever the canal is conducted along the side of a hill, as will happen in a great portion of its length, the level-pegs are not to be placed exactly along the line that the principal engineer has marked out, but either above or below that line, as the slope of the hill may occasion, exactly at that point in every place, where the level of the top bank, that is, one foot above the water line (traced by means of a good spirit-level, with telescopic sights) cuts or intersects the surface of the hill.

In some places it will be found that the principal engineer has drawn his line across the point of a hill, so as to occasion deeper cutting than usual, to avoid going round it; or, on the contrary, crossed a vale or low place, so as to require less cutting or perhaps none at all, to avoid taking a circuit up that vale to follow the level of the ground; and if either of these deviations

should be so considerable that the level-peg would fall more than two chains or thereabouts from the line, down or up the slope of the gound, the plan of having level-pegs upon the surface must be departed from, and holes should, in the first case, be dug, at proper distances in the line, and pegs put into the same with their tops to the right height; or, in the second case, longer and stouter stakes should be used, particularly in the fences that are crossed by the line, or other places where they will not be liable to disturbance, and drove firm into the ground till their tops mark the right level. In tracing these levels, the engineer will refer to and compare his work with all the bench marks before described, and at each end of a level or reach, will level up and down to the bench-marks of the reach above and below the one he has been working at, and compare the same with the fall that the locks at each place are intended to have. And we recommend particularly to the engineer to be very punctual in entering minutely in his field-book the particulars and situations of the several level-pegs, and to make one or more of the men who assist him in levelling, perfectly acquainted with the situations and distinguishing marks of them, and frequently to cause them to be looked over and renewed; or continual repetitions of considerable lengths of the work will be necessary, owing to the disturbance and loss of the pegs by the cultivation of the fields and treading of the cattle, or by the interference of idle and mischievous persons of the country. Too much caution cannot ultimately be taken, by frequent reference to the bench-marks, with due allowance for any accidental variation that may have been discovered among them, and repetitions of the levelling, to avoid those disgraceful blunders into which some less capable and less careful engineers have fallen.

We are now to consider, and we wish to have it distinctly understood, that the great *desideratum* in canal digging is, that the stuff which is dug from one part of the work, shall, with the least labor or distance of moving, exactly supply or form the banks that are to be

raised in another ; so that the work may be completed with the least possible labor, and on its completion, no spoil-banks or heaps of useless soil shall remain, or any ground be unnecessarily rendered useless by excavations or pits.

Several cases will be found often to occur in cutting or forming a canal which will require an exercise of the mathematical knowledge of the engineer. One case, which frequently occurs is, in cutting along or across level meadows, and we were not so well able, when treating of the first survey or projection of a canal, as we now are, to explain a limitation which ought to be attended to in all such level cutting, especially if of any considerable length, *viz.* that the height or level of the canal should be so contrived, that in any cross section, the sum of the areas of both banks shall just be equal to the part excavated or dug.

It will readily be perceived that there are indeed other cases of level cutting, occurring wherever the principal engineer has, in crossing a vale, or point of a hill, found it necessary to preserve his level above or below what would otherwise have been desirable. This is an exception to our rule in the first case, and it occurs in consequence of the elevation or depression of the ground at one or both ends of the level-cutting. The engineer will find abundant instances of this kind, in all their degrees, in which there will be either a want of stuff, or a redundancy from the deep-cutting ; and the perfection of his skill will be shewn in so conducting the line, that every embankment shall have deep-cutting at both, or at least at one of its ends, to furnish the extra stuff, with the least expense in moving it ; and in like manner, that every deep-cutting shall have embankments at one or both of its ends, to receive the extra stuff. It is apparent that cases may occur wherein the canal is conducted along the side or slope of a hill, and where it is evident, that a proper choice of the situation of the canal, higher up or lower down the hill, may occasion the two banks to be exactly equal to the excavation ; in like manner, where the slope of the hill is

so considerable as to admit of no upper bank, the lower bank may be equal to the cutting. It may also sometimes happen on a considerable slope that embanking is required, in order to reach any particular object, or to preserve the most direct line; or deep-cutting may, and often does occur, in sloping ground, but it is unnecessary farther to multiply cases in order to delineate such varieties. An attentive reader will find no difficulty, in tracing, in his mind, every possible variation, by considering the line or surface of the ground to vary in all degrees both of height and inclination, while the banks and canal remain fixed; and from this consideration, it cannot fail of appearing, how essential an accurate knowledge of mathematics is to every engineer, in order that he may be able to make the variety of calculations which may be requisite.

The investigation of theorems for the above purposes would lead us farther into the subject, than would, perhaps, be necessary, especially as no person ought in our opinion, to undertake the direction of such works, who is not only capable of using a theorem laid down by another, but of investigating and preparing rules for every case that can occur or be wanting in his own practice. We proceed, therefore, to advise the resident engineer, on being furnished with the dimensions that the canal and its banks are to have to calculate tables for readily finding the distance of the level-peg, from the middle of the canal, measured on the slope of the hill, let the hill slope with whatever angle it may; or rather let the angle or depression of the slope below the horizontal, top-water line be what it may; and this will be most conveniently expressed, not in degrees, but by the natural sines of the angle of depression; because then if a measuring chain of 100 links be laid down at length, upon the slope of the ground, and the difference of the level of its two ends be taken in links, by the spirit level, those will express the two first figures of the natural sines of the depression, which is quite as great exactness as such tables require. The engineer will now proceed to put in a stake opposite to each level-peg, at

the calculated distance down the slope, for the approximate or supposed middle line of the canal. These stakes will seldom be found for any considerable distance together, to range in a straight or in any other regular line, that will be proper for the canal: and a very difficult and nice part of the engineer's duty is now to be performed, in staking out a new line, with a tallee or a quite different set of stakes from those formerly used, to avoid confusion; this is called staking the middle range of the canal. The requisites in this new line or range for the centre of the canal is, that it should as nearly coincide in every part with the stakes that were last put in by calculation, as possible; that, where, in order to preserve a regular and handsome line, and avoid the awkward, inconvenient and unmeaning crooks and bends, with which too many of our canals, and even some of the latest construction, are almost in every part disgraced, the line is conducted higher than the calculated stakes for one or more stakes together, care must be taken that it shall quickly be conducted below others, so that the redundancy in cutting deeper into the hill in one place may be as exactly as possible balanced by a deficiency just by, owing to the line being conducted below the level-stakes. Besides the consideration above, it will be the time now to estimate the quantity of stuff that will be wanted to land up every bridge and lock, and to give extra thickness to the banks on which any toll-houses, ware-houses, or other buildings, are to be erected, or trade carried on.

In narrow canals, or branches of that description, it will be necessary to provide for wider places at short intervals for boats to turn, and to lie in while others pass them; considerable skill and care are requisite in the choice of proper places for such purpose: they ought to be so situate that boatmen can mutually see each other approaching on narrow canals or branches, and provide for passing, without either of them having to drag their boat back again to a passing-place, as too often happens; at the same time, they ought to be chosen, if possible, in such hollow or low places as will ad-

mit of widening the canal without much extra expense. Another consideration is, the excavation of basons, docks, or wharves, from which stuff may accumulate, which ought to be used up, if possible, in embanking the line just by. Many canal companies have seen it their interest, on proper and timely application from land-owners, who were desirous of erecting wharves, to direct their engineer to calculate upon, and to excavate the additional width necessary for such purpose, at the company's expense ; this and the extra or deep-cutting that there must always be, in the approach to a lock on the lower side, and of embanking on the same approach on the upper side, should always be well considered and accurately calculated ; and full and explicit memorandums ought to be entered in the engineer's field-book at the time, describing where the stuff was calculated to be had for every embankment, and where the stuff is to be disposed of from every deep-cutting or extraordinary excavation.

These memorandums will prove of the most important use in the revisal of the whole length of line or district that is about to be fixed ; as also, in contracting for and letting of the work afterwards, by enabling the engineer, without fear of mistake, to point out which way every part of the stuff is to be thrown or wheeled, as fast as it is dug, and that no part of the same may want moving a second time, or any wide or gouty places be made to disfigure the canal for finding stuff ; or, what is often of more fatal consequence, the canal being dug deeper than usual for such purpose.

After the line shall have been thus marked out with the utmost care, it will be prudent for the engineer to revise it again, and to make pretty accurate calculations of the quantity of stuff wanting, or to spare in particular places ; in these kinds of calculations the engineer will find the most important aid in a ready use of the *slide-rule ;* and we beg here to mention that a gentleman who has long distinguished himself by the various and important uses to which he has made the slide-rule subservient, has prepared a short but complete tract on

its application in the concerns of an engineer, which it is hoped that he will ere long publish. Perhaps, on the review of the line, the curves and bends thereon may in some cases be eased, and beauty and convenience may be more fully attained without much, or often any extra expense.

It will be among the first works to dig out for the foundations of the locks, if they are not already in hand, and for the bridges, if the season of the year and supply of stones or brick and workmen will admit of their proceeding immediately: the several drains or culverts that are to pass under the canal should also be dug out, and prepared for the masons or bricklayers, and the several safety-gates, stop-planks, weirs, and other erections which we shall notice more particularly hereafter.

It may be proper here, to caution the engineer, that in case the pipes of any water-works, or that supply any gentleman's house, cross the line of the canal, such pipes should be laid at once, two or three feet beneath the bottom of the intended canal, with an easy descent and ascent therefrom, and the ground be made good again as soon as possible, both to prevent their being damaged in cutting the canal, and being exposed to frost, or to thieves, if of lead, by lying bare; and in case such pipes are found old or decayed, new and durables ones of lead or cast iron should by all means be laid in the deep part under the canal. The top soil should be carefully removed; and in order to determine readily and correctly the places of the slope-holes which are made on the sides of the canal to designate the width of the ground that is to be excavated, (which width will always vary as the angle of the inclination of the line of the surface of the ground is more or less) the engineer will find it useful to calculate the difference, in length, between a horizontal and an inclined line extending from the level-peg to the middle or to the opposite side of the canal and to form tables adopted to the various inclinations that may occur. Like tables for readily determining the limits of the banks that are to be raised on slopes or inclinations of all degrees that are likely to occur, might also be useful.

Before cutting out the lock-spit, or small trench between the several slope-holes, as a guide to the men who are to dig, the engineer ought to cause holes to be dug in the line of the canal, near every second or third level-peg, or oftener, if the soil be variable, in order to prove the soil to a greater depth by two or three feet than the cutting of the canal is to extend; and each of these the engineer ought carefully to inspect, in order to determine whether puddling or lining will be necessary; and what will be the difficulties of digging, owing to the hardness of the stuff, or to water that must be pumped out, &c.; all which circumstances, as well as the extra distance that any part of the stuff will require to be moved, must be well considered before the work can be let to the contractors or hag-masters, as they are called.

CHAP. III.

PUDDLING AND LINING. WATER-TIGHT STUFF, POROUS STUFF. CASES OF PUDDLING AND LINING.—DESCRIPTION OF PUDDLE AND PUDDLING-STUFF. PUDDLE-GUTTERS DESCRIBED. FORMATION OF THE LOCK-SPIT. LETTING OF THE WORK TO CONTRACTORS. COMMENCEMENT OF EXCAVATION. REACHING. PROCESS OF PUDDLING. WATER FOR PUDDLING. PROCESS OF LINING. USE OF DIRT-BOATS.

THE *puddling* or the *lining* of a canal to make it hold water is a matter of the greatest importance, and we shall consider five cases that are likely to occur or present themselves in the search into the soil that is to be dug by sinking holes as before mentioned. It may, however, be proper, here, to premise, that all soils which will hold water, and not let it soak or percolate freely through them, are called water-tight. The first case

we suppose to be that in which the whole is clay, loam, or other water-tight stuff. Our second case is that in which the whole cutting will be in sand, gravel, loose or open rock, or any other matters that will let water easily through them, and which are called porous soils or stuff. The third case we suppose to have a thin stratum of water-tight stuff on the surface, and then to have porous stuff, extending to a considerable depth below the intended bottom of the canal. The fourth case may have porous stuff near the surface, and water-tight stuff at the bottom of the canal. The fifth case is that where water-tight stuff appears on the surface, below this a stratum of porous stuff, but having again water-tight stuff a short distance below the intended bottom of the canal. New raised banks in all cases, are always to be considered as porous stuff, as indeed they will always prove at first, and in a great portion of soils they would ever remain more or less so, unless either puddling or lining was applied; and all ground that has been dug or disturbed must also be considered as porous. It should also be remarked that any kind of soil which is perforated much by worms or other insects, should in canal digging be considered as porous stuff.

Puddle is not, as some have attempted to describe it, a kind of thin earth mortar, *spread* on places intended to be secured, and suffered to become *quite dry* before another coat of it is applied; but it is a mass of earth reduced to a semi-fluid state by working and chopping it over with a spade, while water, just in the proper quantity is applied, until the mass is rendered homogenious, and so much condensed, that water cannot afterwards pass through it, or but very slowly. The best *puddling stuff* is rather a lightish loam, with a mixture of coarse sand or fine gravel in it; very strong clay is unfit for it, on account of the great quantity of water which it will hold, and which disposes it to shrink and crack as this escapes: vegetable mould or top-soil is very improper, on account of the roots and other matters liable to decay and leave cavities in it, but more on account of the temptation that these afford to worms and

moles to work into it, in search of their food. Where puddling stuff is not to be met with, containing a due mixture of sharp sand or rough small gravel stones, it is not unusual to procure such to mix with the loam, to prevent moles and rats from working in it; but no stones larger than about the size of musket bullets ought to be admitted. That the principal operation of puddling consists in consolidating the mass is, we think, evident, from the great condensation that takes place — It is not an uncommon case, where a ditch is dug, apparently in firm soil, that though great quantities of water are added during the operation, yet the soil that has been dug out will not more than two thirds fill up the ditch again, when properly worked as puddle. It would seem also, that puddle, is rendered by that operation, capable of holding a certain proportion of water with great obstinacy, and that it is more fit to hold than transmit water. It is so far from being true, that puddle ought to be suffered to get quite dry, that it entirely spoils when by exposure to the air it is too much dried; and many canals which have remained unfilled with water during a summer, after their puddling or lining has been done, have thereby become very leaky, owing to the cracks in the puddle-ditches and linings. One of the first cares of an engineer, when beginning to cut a canal, is to discover whether good puddling-stuff is in plenty, and if it be not, it must be sought for and carefully wheeled out or reserved, where any is found in the digging; or perhaps procured at considerable distances from the line, and brought to it in carts. It has happened in some stone-beach, or loose rocky soils, that all the puddling-stuff for several miles of the line, required to be brought to it; but even this expense, serious as it may be, ought not to induce the copying of those, who have left miles of such banks without any puddling, and have made a winter canal, but which no stream of water that is to be procured can keep full in the summer months.

If we compare our first, fourth and fifth cases, we shall find in all of them a water-tight stratum as the ba-

sis ; and the best practice is, in these cases, to make a wall of puddle, called a puddle-ditch, or puddle gutter, within the bank of the canal ; these puddle-gutters are usually about three feet wide, and should be sunk about a foot into the water-tight stuff, on which they are always to be begun ; and they should be carried up as the work proceeds, to the height of the top-water line, or a few inches higher. They should also be carried up perpendicularly, so that the settling of the bank may not crack them by any lateral pressure. In order to secure them from the operation of frost and other disturbances, it will be best to make them so far within the bank, as, that, if continued up to the top thereof, they would be at least a foot from that edge or extremity of the upper surface of the bank, which is next to the canal. Our second and third cases evidently will not admit of the above mode, because we have here no water-tight stratum on which to begin a puddle-gutter as a bottom : in these cases, therefore, it is usual to apply a lining of puddle to the sides and bottom of the canal. The process of puddling and lining will occur more properly further on, as we proceed in describing the operations of digging and forming the canal.

After the engineer shall have determined by a careful inspection of the soil, as before directed, what part of the canal will require to be puddled, he will proceed to mark out the puddle-gutters by digging small holes or nicks as a guide to the laborers. Where lining is to be applied it will be proper that the canal should be dug five feet deeper than would otherwise be necessary ; and five additional feet must also be excavated from each of its sides : the engineer will therefore, in this case, proceed to designate, by proper slope-holes the two extremities of the part to be excavated. A skilful and very handy workman is now required to mark out the line upon the ground, called the lock-spit, between the slope holes, which we have supposed to be made at about two or three chains from each other, along both sides of the canal, exactly embracing the part that is to be dug. The workman begins, by laying down and

stretching a strong line upon the ground, between two or more adjoining slope-holes, and if the canal is not to be straight in that part, with small pegs to give it the gradual and regular bend in every part that the canal is to have; the workman then proceeds, holding his spade or grafting tool not upright, but always with the slope that the bank is to have, and strikes it successively into the ground close to his line, until the whole length of the line is marked out; by this means if the ground has sudden undulations, or hollows, as continually happens, owing to the ridges and furrows of cultivated lands, and other causes, yet a regular line is marked out upon the surface; before the line is taken up, another laborer follows on the other side of it, and strikes in his tool inclining the contrary way, by which a triangular sod or piece of earth is cut and thrown out. It is obvious that this operation is to be performed on both sides of the canal. If neatness and regularity are consulted, the engineer will also, designate by proper marks the extremities or outsides of the banks. It may be proper, here to remark, that canals set out with the scientific precautions and care that we have recommended, will always have the proper quantity of stuff to allow for the settling of the banks, because the solid contents of the banks after they have become consolidated and compacted will always be equal to that space of the canal which they occupied before excavation. It will not be amiss, to give the contractors a table or rule shewing, according to the elevation, what extra height a suddenly raised bank ought to have, in order to allow for settling: and it is evident that the slopes of such banks must be steeper in the first instance, than they are intended ultimately to be.

We may now suppose the engineer to proceed to the letting of the cutting of certain lengths of the canal to contractors or hag-masters, who will employ, under them a number of navigators as they are called, in digging and puddling the canal. It is usual to let the work at a certain price per cubic yard of digging, and to pay for the puddling or lining either at a certain price per

cubic yard, or per yard run of the canal. The engineer ought to inform himself thoroughly of the difficulties and facilities which attend the work he is about to let, and to draw up a short but explicit contract to be signed by the contractors. We cannot but recommend that all contracts for material or large jobs of work, not only in cutting, but for the mason's, and other works in particular, should be submitted to the principal engineer for his approbation, before they are signed or finally concluded. The prices allowed ought to be fair and liberal, according to the circumstances, so that the contractor may have no pretence, on account of low prices, to slight his work, particularly the puddling; and they ought in every instance to be strictly looked after, and made to undo and renew immediately, any work that shall be found improperly performed. We recommend it to the engineer to keep a strict account, by means of his overseers or counters, of all the men's time that are employed upon the works; distinguishing particularly the number upon each work, and whether employed by the day, under the company, or upon the work that is let to contractors. These particulars are most essential towards knowing, what money ought to be advanced to the contractor during the progress of his job, and towards informing and maturing the judgment of the engineer, in the length of time that a certain number of men will be performing any future work that he may have to direct; and a calculation ought to be made in every instance of the number of days-work, and compared with the contract price, by which alone a correct judgment can be formed of the proper prices at which work ought afterwards to be let, so that the laborers may receive proper wages, proportionate to their exertions, and the contractor be amply paid for his time, skill and superintendance; and yet economy and the interest of the company be duly consulted. Barrows and wheeling-planks, horsing-blocks, and other implements, are generally found by the company; and it is usual to consider from 20 to 25 yards, to be a stage of wheeling, and a price per cubic yard to be fixed according to the number of stages that

the soil is to be moved. Where this distance exceeds 100 yards, it will not often be eligible to perform it by wheel-barrows; and runs of planks with an easy descent, if the same is practicable, should be then laid for large two-wheeled barrows, or trucks to be used thereon.

The cutting of a canal being let, the work is usually commenced by a laborer on the lower side of the canal; and from the lock-spit he marks out a certain width towards the middle of the canal, such, that he can throw or cast the stuff as he digs it to the extremity of the bank, and so that the heap may not obstruct the intended puddle-gutter. The side of his work at the lock-spit he must be careful to cut down with the proper slope of the bank; while the opposite side is usually cut straight down, and this work is continued until he comes to the bottom of the intended canal; and this space which his work occupies is called the "reaching." The same process is followed on the lower side of those parts of the canal that want lining; except that the "reaching," in this case, is to be accommodated to the extra width and depth of excavation preparatory to lining as before mentioned, and as there is no puddle-gutter to be provided for, it will not be necessary to throw the stuff further, in this case, than that it may lie without falling back into the work; and it is usual, if the reaching will not be very deep, to lay two or three rows of sods or sound spits of earth, with regularity in the face of the slope to form part of the bank, and to throw the other stuff over these. Reachings are also to be dug on the upper side of the canal, and as much stuff is to be thrown out therefrom as the inclination of the surface of the ground or the height of the bank to be raised may require.

It is now time to commence the puddling; and a laborer begins by digging out the intended puddle-ditch to the bottom. If the soil dug out is good puddling-stuff, he lays it along between the puddle-gutter and the canal, if not he throws it at once back along with the stuff dug out of the reaching. A careful examination of the

face of the reaching or sloping bank of the canal, will shew to what depth the puddle-ditch ought to be dug in every part, to reach and intersect any faulty places, or veins of lighter soil, or worm, rat, or mole-holes that may accidentally occur in the bank.

After the puddle-ditch is dug clean out to its proper depth, and this is a circumstance that the engineer or some careful overseer ought to look particularly to, about 9 or 10 inches thereof is to be filled loosely up with puddling-stuff, either from that which comes out, or from the nearest heap in reserve, all large stones, sticks, straws, or other extraneous matters being carefully picked out as the stuff is sprinkled in: by this time, unless the season is very dry, it is probable that some water will be collected in the bottom of the reaching, and this should be laded out with a scoop into the puddle ditch, so as to give the stuff therein a good wetting; if the puddle-stuff be of the stiffer kind, or was very dry, it will be right for the laborer to betake himself to some other part of the work, for two or three hours, in order to give the water time to soak through and pervade the whole mass, but perhaps giving his stuff another sprinkling of water in the interim; he may then proceed with the puddling; and for this purpose he ought to be provided with a stout pair of puddling-boots, that keep out water; he begins at one end of the trench, and keeps chopping with his tool into the stuff and quite through it, giving his tool a lunging motion every time before it is withdrawn, so as to let the water into, and to stir every part of the puddling-stuff; if more water is wanted, another laborer is set to lade it out of the reaching as before; and the puddler thus proceeds, chopping down at every inch or thereabouts as he slowly advances, and trampling about at the same time as much as he can with his feet, which greatly assists the operation: when arrived at the end of the trench he turns round and repeats the same operation back, and so on, until every part of the puddle is properly worked; which is known by the tool going equally easy into it in every part, which it would not do if any dry lumps remained,

and the whole being in a semi-fluid state; giving the puddling-stuff just the due quantity of water is very essential to its working well, and this, experience will soon point out.

Very great care and management will, in general, be required on the part of the engineer, to furnish water for puddling: it will often be necessary to bring it in temporary trenches, perhaps across several fields from some mill-dam, large pond, or spring of water above the canal; for which purpose, general powers ought to be given in the act, upon condition of levelling and making all such trenches good again as soon as possible, and paying for the damage; often times puddling-water is not to be had, without pumping it up, and conveying considerable distances in troughs, of which great numbers will be required. It will very often be requisite to convey the water across the canal in troughs to the different puddle-gutters, and plenty of trestles should be in readiness for supporting these troughs at the requisite heights. Considerable care will be necessary to turn off the surplus water, into some channel where it can run off without flooding the works; or to stop it at its source; this last ought always to be adopted, when the supply is not very plentiful, or the owner of the stream or pond might be injured by taking a constant stream from him, during the progress of the work. The first or bottom course of puddle being properly worked as above, it should then be allowed to stand two or three days undisturbed, and without any more water being given to it; when it will be found sufficiently set, so that a man may step on it without sinking in; it is then ready to receive a second course; the first step is, to scrape off and remove any lumps of earth, stones, sticks or other matters that may have fallen into the puddle-gutter; about 10 inches thick of puddling stuff is then to be lightly sprinkled into the ditch as before; and water is to be applied either from the reaching or some other source; some hours time is to be allowed for the stuff to soak, unless it be light loam, and moist at the time of putting it into the ditch;

in such case the puddling may be begun almost immediately: care must be taken that the tool be made to penetrate a small distance into the first course, so that the two layers may be properly incorporated. After this course is properly wetted and worked, it must stand the proper time to set as before, but by no means to get dry, otherwise it will be found full of cracks and must be worked anew: and in case, owing to any temporary suspension of the work, it should be necessary to leave a puddle-ditch before it is finished, it ought always to be covered and left with a dry or unworked course of puddle-stuff upon it, to keep the air from it and preserve the proper moisture in it.

When a sufficient number of courses of puddle have been added, to fill up the puddle-ditch to the surface of the ground, two or three rows or courses of sods, or spits of earth, must be laid on each side, to raise the ditch so much higher; at the same time that the heap of stuff that had been thrown out of the reaching is levelled down to support the outside of the puddle-ditch, while the sods on the inside next to the canal are backed up by other stuff brought by the men who are wheeling from the bulk that had been left in the middle of the canal. In like manner successive courses of sods and of puddle are to be added, the sods being backed up as before until the puddle is carried up to the top-water line, or one or two inches higher; care being taken to lay spits of earth to form the slopes of the bank as the work proceeds upwards, particularly the inside slope which should be well trod and consolidated by strokes of the tool to prevent its falling down, or being disturbed by the water when the canal is filled. After the upper course of puddle is properly set, the bank is to be continued, covering the puddle completely with common stuff, until the intended height of the top-bank is attained, with proper allowance for settling; and observing that the puddle will not settle near so much as the other stuff, if at all. The other bank of the canal and its puddle-ditch are to be carried up in the same manner.

The part of the canal with puddle-gutters of which we have been speaking, has, in general, a lump or ridge of stuff remaining in the middle of its bottom, until the very last: a different system must, however, be pursued with such parts as require to be lined; here, the banks may be at once made up, and the whole of the bottom, down to the depth heretofore mentioned must be cleared, for certain distances before the lining of the bottom can be begun. A great deal of management is required by the overseer or contractor, to direct all these parts of their business, so that there is no hindrance of any part of the work, that every man is provided with stuff by the wheelers, when he wants it to make up his banks, or to puddle, and that the parts to be lined are cleared in time. To accomplish all these objects, a good part of the stuff cannot be wheeled directly out to the nearest or opposite points of the bank, but it must be worked forwards and backwards obliquely, on the runs of wheeling planks, by the wheelers, as occasion may require. It may often be necessary to exceed one or two, or perhaps more, stages of wheeling, to avoid taking out the stuff and clamping it, by which it would require filling again, damage would, in most cases, be incurred in the adjoining lands, and frequently the puddling and working of the banks would be impeded, by crossing them to land the stuff.

A length of the canal that is to be *lined* being cleared, and the bottom levelled and cleaned smooth down to the necessary depth, a course of puddling-stuff about 10 or 12 inches in thickness is to be spread over it, with all the precautions to extract extraneous and hurtful matters, which have been before given, and the whole is to be wetted and allowed to soak if necessary, as before: the working of this puddle is now to be begun; and as the extent will generally be large, several men may be employed, at once, upon it, so as to make it worth while for an overseer employed by the company to attend them constantly to see that no part of the work is slighted; as the bottom in this case is supposed to be loose rubble of a rock, sand, chalk, gravel, or other mat-

ters, that would injure the puddle if mixed therewith, we have recommended a thicker course at first than is usual of puddling-stuff, and in working the same the men ought not to strike their tools deeper or even quite so deep as the bottom of the puddling-stuff to avoid disturbing the bottom. When this course of puddle has been allowed to set, another, of about 9 inches is to be added, and treated as before, till about three feet of puddle is added, if the soil is very porous; and the top course being set, a course 18 inches or two feet thick of the common soil or stuff should be laid evenly upon it and levelled; this covering of the puddle should be rather dry, and not in large lumps, or with great stones or sticks in it.

The *lining of the sides* is now to be proceeded with as follows; the covering which lies on the puddle should be removed for three feet in width next to each of the sloping banks, and the surface of the puddle be carefully cleared of dry lumps, stones, &c.; a thickness of nine inches of good puddling-stuff is now to be laid on the naked puddle, and wetted, and worked, and allowed to set, as before, when another course is to be added in like manner; sods or spits are then to be brought from the common digging of the canal, and carefully piled up for two feet in width and about nine inches in height (to support the puddle,) hatching or inclining back before and behind, agreeable to the slope of the bank, the face of which they are to form, and leaving a space or puddle ditch behind, and the interstices between the sods should be filled with fine stuff to make the whole solid; in this manner successive courses of puddle are to be added, supported by accumulated layers of sods as before until it reaches a little above the top-water line, when the remainder of the bank may be formed of common stuff faced by compact courses of spits or sods. This last way of making a canal tight, by lining it, is the more tedious and expensive of the two; it is, however, general, and may be applied in the most loose, open, rocky and porous soils with perfect success.

In case it is found that there is stuff to spare after completing the banks, it may be disposed of by filling up the hollows above the upper bank so as to turn the water into the culverts that pass under the canal; or, if not wanted for that purpose, it may be thrown into a heap or spoil-bank to be afterwards boated away as occasion may require. It must be evident however, that these resources are inadequate to receive any great redundancy of stuff. A good resource to supply a deficiency of stuff may be provided, by marking out a yard or two or more in width to be purchased on the upper side of deep cuttings, by which a great deal of stuff may be procured at a comparatively small expense. Such means as above will be sufficient where the canal has been laid out with the most scrupulous care: bungling, or careless canal-makers must be content to leave lasting marks of their incapacity or folly behind them, in the many sudden bends into the hill that they are obliged to make to obtain stuff, and out of it to dispose of the same in other places, with numerous wider or deeper places on the canal to make up the banks, or in enormous spoil-banks or useless excavations. Where a reserve of stuff has been made in the deep-cuttings at several points on each level or reach of a canal, as above mentioned, it will be the better fault of the two, to experience a deficiency of stuff; because, as soon as the bottom of the canal has been cleared, and the lining of the bottom and sides for some height performed, or the puddle-ditches carried up, the canal may have 18 inches or 2 feet of water let into it, and dirt-boats may be used to carry stuff from the deep-cuttings to make up the banks in other places; whereas all redundant or spare stuff must be got out before the bottom lining can be applied or any effectual use made of boats to move stuff from place to place; and the same advantages will be experienced in situations where puddling-stuff is only to be procured at particular points on the line, by clearing out and completing the bottom part of the canal for considerable lengths, so that dirt-boats may be used for bringing the same for the puddling or lining

the upper part of the banks, which, if there is spare stuff, cannot be effected without heavy expenses in moving the same and forming spoil-banks.

Where the line of a canal is to cross an extensive stratum of valuable clay for brick making, or one of good gravel for making of roads, it will often be advisable, especially if the line can be rendered more direct thereby, when setting out the canal, to cut pretty deep into such materials, and even quite through the gravel, if the same is practicable; for although considerable expense will in the first instance be incurred in digging and in damage for spoil-banks, yet such materials, as good brick-earth and gravel, will in almost every instance find a market as soon as the canal is opened; such a situation of the canal may prove of essential service to its trade, by enabling the adjoining proprietors to work the whole thickness of their brick-earth, gravel, or other useful matters, and destroy but very little of the surface of the ground, and without being annoyed by water, but which the canal would catch in very considerable quantities perhaps, instead of losing water by preserving a high level through porous stuff. It is highly to the interest of a canal company to give facility to the getting and conveyance of all useful articles within their district, at the cheapest possible rates, as the only means of opening new sources of trade or manufactures, by which their concern will be most essentially benefitted.

In districts where stone and gravel for making and repairing roads are scarce, it will be proper to pay the laborers certain rates per cubic yard for all the stones or gravel that they may collect out during the work, and stack in proper places; as resources for making the towing-path, and for making good the landing or ascent to the several bridges, and the several pieces of new road that the engineer will have to form, near to the canal and bridges; the lock-banks and all wharves and landing places should also be covered with good gravel, to render them safe and convenient for use: if good gravel can in places be intersected in deep-cuttings, much of the above expense, as well as of cartage, may

be saved by an early use of dirt-boats in the bottom of the canal

It cannot we think, have failed to strike every reader, ere this, how very important and various the duties of the resident engineer are; but the same will be much more apparent, when we shall have finished in the following pages, our observations under the heads of reservoirs, feeders, aqueducts, embankments, culverts, safety-gates weirs, tunnels, deep-cuttings, locks, bridges, towing paths, boats, &c. &c. of which we shall proceed to treat; after observing, that none but men of the strictest integrity and extensive knowledge ought to be employed as resident engineers, and that the committee and principal engineer ought not to hesitate in offering and paying such men a very liberal salary, to engage the whole of their time; and, that too great a length of line or extent of business should not be put upon such a man. This is the proper sphere, where young men or others of knowledge and persevering industry, who are coming forwards in their profession, should exercise and give specimens of their abilities as engineers; and it will prove of the utmost importance to such, as well as to a company who have an extensive line of canal to construct, to employ more than one of such men at the same time, upon adjoining lengths of the canal; where their emulation may be excited in an honorable contest, as to which of them shall execute his portion of the business in the most complete, orderly and economical manner.

CHAP. IV.

RESERVOIRS. CALCULATIONS OF THE QUANTITY OF WATER GAUGING SPRINGS AND STREAMS. EXAMINATION OF THE GROUND FOR A RESERVOIR. SLOPE OF THE HEAD. LAYING OUT THE HEAD. ARCH AND WELL. COCK AND PIPE, FOR DISCHARGING THE WATER. SYPHON CHARGED WITH MERCURY. GAUGE-PUDDLE. ENUMERATION OF THE PRINCIPAL RESERVOIRS.

ONE of the first considerations relating to the *construction* of a *Reservoir* for supplying a canal, is the supply of water that is to be expected for it, and in what proportions at different times of the year: for this purpose we suppose the engineer to be furnished with an accurate survey of the vale or vales that lie above the intended reservoir, so as to be able to calculate exactly, how many square miles and fractions of surface drain towards or vent their rain-water through the part intended to be embanked for the reservoir; it will be very proper also to be furnished, if possible, with the exact gauge or quantity of water that has actually in former years been discharged by the brook or stream that is to be embanked; as also with the quantity or depth of rain which usually falls within the drainage of the intended reservoir. If the length of time that has elapsed, since the situation of the reservoir has been determined on, has not allowed of careful and accurate experiments being made on these points, the engineer must assume them from the best data that the information of millers and other persons will afford, and the printed tables, or journals of rain, kept by curious persons in the nearest similar situations, must be consulted: it is particularly necessary to attend to this last circumstance, because there are we believe, instances of places where the annual depth of rain does not amount to a foot, and others in which it exceeds five feet; while 23 inches is about the medium depth of rain annually at or near London.

The most perfect method of obtaining true information on this subject, is to gauge the different springs or streams, from whence the supplies of water are to be derived, and thus to ascertain the exact surplus, after the mills are amply furnished. In the great contest about the Rochdale canal, Mr. Rennie had all the streams, which could be affected by the proposed reservoirs, gauged for about a year. He first ascertained the state of these streams at a time when the mills were amply supplied with water and had proper gauges fixed upon them. The daily difference was measured, and the surplus thus ascertained amounted in the year 1793 to sixteen times the ordinary produce of the rivers. The evaporation that takes place, from a given surface of water in different places, has not yet been so accurately observed, as the importance of the subject to canal engineers deserves ; *Mr. Bevan's* observations thereon, in Bedfordshire, continued for five years, to the end of 1804, gave an evaporation of 22.92 inches at a medium per annum, while the depth of rain there, in the same period, averaged 23.28 inches ; in some years the evaporation considerably exceeded the depth of rain, and in others it fell as much short of it or more.

It will sometimes happen, that the valley in which the reservoir is to be made, has other valleys parallel to it, on one or both of its sides, such, that by beginning a sough or small tunnel above the level of the reservoir, continuing it with a small rise through the adjoining hill, and from its further end continuing a ditch or feeder along the side of the hill rising gently as it proceeds till it intersects the bottom of the vale, a brook or considerable stream of water may at times be there intersected and brought into the reservoir ; or another case may happen, in which the adjoining valleys instead of being parallel to, proceed directly from the reservoir valley, and yet feeders may be set out, so as to collect great quantities of rain and spring water, from the sides of the hills that slope towards the adjoining valleys, and through which it would otherwise escape.

The engineer, who has well considered and ascertained all the circumstances of the vales in or near to which his reservoir is to be constructed, will be able, by help of a number of levels, carried round to where the surface of the water will extend at every 5, 10. 15. 20, &c. feet in depth, or oftener, if the unevenness of the ground requires it, to calculate to what height the mound, dam, or head of the intended reservoir must be embanked or raised to retain all the water that his valleys can supply, between the times that it is fed by rains and springs, and required to be let off to the canal or to mills, or such quantity only as it may be necessary so to retain, according to the principles before laid down.

The necessary height of the head or embankment for a reservoir being determined, the next step will be to examine minutely the nature of the strata and soil that are to be covered with water, and whether the whole or any part of the same is so porous as to require lining with puddle, as also the nature of the stuff which is to be used in forming the head or bank to dam up the water to the necessary height, as thereon will depend, in a great measure the degree of slope which the banks ought to have ; one and a half to two feet base to one in height is the usual degree of slope ; but if the soil should prove a slippery clay, as at the Aldenham reservoir, belonging to the *Grand Junction* canal, a greater slope should be given, as well as the precaution taken, of putting in frequent layers of sand or coarse gravel, to lessen the tendency of such soil to slip. If the reservoir will require bottom lining, yet still, it will not sometimes be right to trust to lining for the head of the reservoir, but to carry up a puddle ditch in the center of the head, because if the inside of the head should happen to slip, the lining would be broken and disturbed. The slopes being settled, it will be right to make a cross section of the valley at the place of the center of the head, and to determine by levelling, and mark out the places of as many perpendiculars or equidistant ordinates as the length of the head across the valley, and the nature of the sides of the hills may require.

The height of the several perpendiculars, corresponding with the top-level of the intended embankment, being thus obtained, the engineer will find no difficulty in calculating and laying off from each of them the extremity of the base of the head or embankment, taking care to make the due allowance for any variation of the surface of the ground from a horizontal line: the engineer will cause slope-holes to be made; and a careful workman, after pegging down his line, by holding his tool in an inclining position according to the slope of the intended embankment, will mark out a lock-spit, as a boundary or base to the embankment. The engineer will now proceed to calculate in cubic yards or feet the solid contents of the required bank; and the most eligible spots for obtaining the necessary quantity of stuff, without endangering the slipping or stability of the bank, may be marked out; and the work will then be in a state to be let to the contractors, who are to execute it. But before this work is begun, it will be necessary to provide for the escape of the surplus water when the reservoir shall be full, as also for letting out the water for use; for these purposes an arch of brickwork, or of stone, may be begun at the lower limit of the bank in the lowest ground or brook course, and the same should be continued on a level to a point a considerable distance within the head of the reservoir. This arch should be high enough for a plank to be supported and fixed on irons or bearers across it, about a foot from its bottom, on which a man can conveniently walk along; and for this purpose, the arch had better be made elliptical, or higher than it is wide; a secure iron gate should also be provided, to be kept locked, at a few yards into the arch, from its outward extremity, for excluding improper persons. At the inward termination of the level arch there should be a circular well of six or eight feet diameter more or less, according to the greatness of the floods that may be expected, to be sunk six or seven feet deeper than the arch; its bottom should be formed either of one very large flat stone, or of a few well jointed ones laid on a course of

puddle, and on this the steining of the well should be begun, with bricks of the very best quality, well keyed up and embedded in cement; and having a course of puddle nine inches or a foot thick, worked all round behind them, allowing the same to set as the work advances in height; this well and the arch are to be securely groined into each other; near to this groin, or within reach of a man standing on the end of the plank above mentioned, which should not advance quite up to the well, should be a large brass cock worked into the walling; the mouth of this cock should be turned down, so as to discharge its stream of water exactly in the direction for the center of the bottom of the well; and from the cock should proceed a large pipe of lead or cast iron behind the wall of the well at some distance, for which purpose it will require a considerable bend, and this pipe should proceed from the cock, soundly embedded in good puddle, to a convenient place in the bottom of the reservoir, above the embankment, where it should terminate under a large and stout box full of holes, or a fine grating, to prevent the entrance of fish or any thing that might choak the pipe or cock. In constructing the arch before mentioned, after it has proceeded as far as the intended puddle ditch, (which we have recommended to be carried up in the center of the embankment, and which will cross the arch) the puddle-ditch should be dug out for some distance on each side across the arch; the same should be continued down to water tight-stuff, or at least for some depth into other matter, if unfortunately such is not within reach; and when the puddle is carried up and set, as also a course of puddle in the bottom of the arch course which should have been dug deeper for such purpose; the bottom of the remainder of the arch should be carefully laid on the puddle, and a centering for the arch is to be laid on the same and firmly secured down, this precaution being necessary to prevent the semi-fluid puddle that is to be applied successively, outside of the arch as it is carried up, from floating or burying up the centering along with the lower part of the arch. The work is thus to

proceed until the part of the arch from the puddle-ditch to the well is completed, and enclosed completely in a case of good puddle, thoroughly and completely joined at one end into the puddle-ditch, and into the puddle that surrounds the well at the other. When the well-steining has been carried up to the bottom of the arch, it will be necessary to increase the thickness of the puddle-wall round it, to three feet or more, taking care that the extra width is firmly bedded upon undisturbed and solid earth. The well is intended to be carried up in like manner, surrounded by puddle and by a conical embankment of earth, to within two feet of the height of the bank, leaving a channel of several yards wide, and of considerable depth, between it and the bank or head. It will be necessary for the engineer to calculate and mark out the base of this conical embankment (which is to support the puddle round the well) upon the ground, with allowance for ample slopes to prevent slipping or its washing down : it will also be proper, for ensuring stability to the work, to reduce the whole of the top of the work to one level, as soon as can be, by successive layers of stuff thereon, and of puddle in the puddle-ditch and round the well : and if the bottom of the reservoir requires lining, owing to the porosity of the soil ; it will be right after levelling and treading the part adjoining and under the intended embankment, to cover the same with 3 or 4 courses of puddle, joining the same perfectly with the puddle-ditch, and the puddle round the well, to which courses of puddle the bottom lining is afterwards to be carefully joined ; and after this is properly set, the remainder of the bank and of the cone round the well may be proceeded with, as we have before mentioned, when treating of the rearing of canal banks with puddle-ditches in them. The bank or head being completed to its upper surface, and the well and conical embankment being also carried up to the proper height, the well should then be coped with a layer of the best hewn stones cramped together, and the top reduced to a perfect level ; and for security, it will be right to pave the surface round the well and for some

distance down the sides of the conical embankment, with paving stones pretty well jointed, and set their longest way into the soil, filling their joints with mould, and sowing grass seed therein to prevent the waves from afterwards loosening the stones or wearing the bank; this conical bank is for enabling the water to fall into the well on all sides; if the well was made in a corner of the reservoir, much digging would be required, both for the arch or pipe to let out the water, and for the discharging arch.

We have been thus particular in describing the circular weir or well-fall above recommended, from having seen the beneficial effects of one, in the reservoir near the Duke of *Bridgewater's* canal; and the mischief that is sometimes done to the banks of a reservoir and the adjoining lands, by letting off the flood-waters by common wiers or tumbling bays at the corners of the reservoir, and suffering it to find or rather tear its way down into the valley. Reservoirs constructed on the above principles would be secure almost from accident, however high the embankment, or sudden and copious the floods, if the well is but made sufficiently large, and deep of water at the bottom, to receive the shock of the descending column of water. If the floods are so considerable as to bring down timber and other large floating matters, it will be necessary to fix a strong grating or circle of bars round the top edge of the well bank — It will be proper, that the core or plug of the cock to a reservoir should be turned by an endless screw, or by toothed wheels, so that considerable power and nicety in the adjustment of the stream let out, by the turning of the cock, may be attained; and a register should be provided of the number of turns, and fractions of a turn, that is given to the winch or handle in any case. It will be proper to flaunch on a small pipe to the large one, and connect the same with an inverted glass syphon filled with mercury, in the arch near the well, so that by turning a cock the, height of the mercury should indicate on a scale attached, what depth of water there is in the reservoir above, or how much it wants of being full at

the time. A series of accurate experiments should be made, by gauging the stream of water at the discharging end of the arch, or at the first convenient place below it, ascertaining thereby how much the cock discharges per hour or day, when the water is at different heights in the reservoir, and with different turns of the cock-geer: these should all be repeated, and sufficiently numerous, to enable the engineer by interpolation, to fill up and form a table, (copies of which the committee ought carefully to preserve) by which at any given height of mercury, the cock can readily be set to discharge any number of locks full of water that may be required per day. No great difficulty would attend the forming of a gauge-puddle, instead of, or by the side of the brass cock that should regulate itself, and discharge any regular and constant quantity of water that the reservoir could supply: see *Leybourn's Repository*, 8vo. p. 165. It will be right also for the engineer and committee. to have tables for readily shewing the quantity of water that every reservoir contains, at each foot or shorter portion of its depth, indicated by the mercury in the syphon. or by a graduated gauge-post fixed up in any part. For forming a table of this sort, where a complete survey had not been made or preserved at first, the time of a hard frost should be chosen, and a sufficient number of holes at equal distances, in a great number of parallel or equidistant lines, should be bored or cut through the ice sufficiently large to let down a plummet to sound the depth, and if this is done with care when the reservoir is full or nearly so, a most correct table of its contents at different depths, can be thus obtained by calculation. Some of the considerable reservoirs that have been constructed for canals, are at Aidenham, Daventry, and Wilstone on the *Grand Junction*; Kilsyth on the *Forth and Clyde*; Branstone, and Denton on the *Grantham*; Ripley on the *Cromford*; Amsworth on the *Nottingham*; Littleborough on the *Rochdale*; Marsden on the *Huddersfield*; Oxendon on the *Leicestershire and Northamptonshire Union*; in Rudyerd vale near Leek, for supplying the Caldron branch of the *Trent*

and Mersey canal, which covers 160 acres, has its head 30 feet high and the water in general very deep. St. Ferriol reservoir constructed about the year 1670, on the canal of *Languedoc* in the south of France, occupies a space of 595 acres, its banks are walled round with free-stone, and its waters let out when wanted, by a large pipe and cock.

CHAP. V.

FEEDERS. CONSTRUCTION OF FEEDERS. GAUGING THE QUANTITY OF WATER. KNOWLEDGE OF THE STRATA. SINKING THE SUMMIT LEVEL FOR A RESERVOIR.—CONSIDERATIONS THEREON. AQUEDUCTS. AQUEDUCT BRIDGES. THEIR FORM AND CONSTRUCTION. CAST-IRON AQUEDUCTS. THEIR CONSTRUCTION ACCORDING TO R. FULTON. STUPENDOUS AQUEDUCT ON MR. FULTON'S PLAN OVER THE RIVER DEE. ENUMERATION OF THE PRINCIPAL AQUEDUCTS.

IN *constructing feeders* or channels to convey water to a canal from springs, brooks, or reservoirs above its level, the same care must be taken to examine the nature of the soil in every part, and to apply a lining of puddle, as have before been mentioned respecting the line of a canal, wherever porous stuff is to be cut through. Where there are a great number of undulations in the ground, through which a feeder is to be conducted, that would occasion it to be very crooked and much impede the cultivation of the land, it will be proper, in many instances, especially if the land be valuable, to cover over the feeder in a culvert or small arch of bricks, of 18 inches or 2 feet diameter, or larger if the supply at any time will require the same. In very porous soils, these culverts, inclosed in puddle, will be the most effectual way of preserving and conducting small streams

of water, and no land will thus be lost to cultivation. In some places, feeders will require considerable embankments and aqueducts, to cross valleys and streams of water, and preserve their level, or gradual and small fall; and in many of such cases, it will be cheaper and better to use cast iron pipes well jointed and flaunched, and laid within the ground, down one side or bank of a vale to be passed, and up the other, securing each end carefully with a strong box full of holes, or a fine grating, to keep extraneous matters out of the pipe. It has often happened, where reservoirs are situate at some distance above a canal, and a brook course led from the reservoir to the canal, that the water was left to take its ancient course on being let out of the reservoir; an expert engineer, will, however, carefully examine all such feeders, for thus they ought to be considered, and fill up all deep holes, and lower the shallows in the brook-course, so as to reduce the channel nearly to an uniform width and depth; and very accurate gauges of the water ought to be made at different seasons of the year, of the quantity issuing out of the reservoir arch, and the quantity received into the canal; if these differ materially, intermediate and comparative gauges should be made of the stream, until the faulty or leaky ground is discovered, probably some stratum of sand or open jointed rock; over which the brook-course or feeder ought to be carefully lined with puddle; and if puddling stuff be scarce, the soil very porous, and the brook-course very crooked, it may be the most effectual way as well as the cheapest in the end, to pass such leaky ground by a small culvert, inclosed in puddle under ground, by the side of the brook-course, as straight as the course of the valley will admit. Except in situations, where mills in the vicinity of an intended canal are much in want of water, or their owners or others disposed to thwart the scheme, it has been usual to allow the company to search for, and divert to their use all springs of water within certain limits on each side of their line; in the acts for the *Newcastle underline Junction*, the *Southampton and Salisbury*, and the upper part of the *Tamer Manure* ca-

nals, this limit is fixed at 1000 yards; in the *Aberdeen*, *Polbrook*, *Tamer Manure*, lower part, *Thames and Medway*, *Wilts and Berks*, and others, this is fixed at 2000 yards on each side of the line. In such cases an accurate investigation and knowledge of the *strata*, upon Mr. *Smith's* principles, will be of the most essential importance, in order to collect and retain springs that are above the summit level, or even lower, in situations, where a local trade is to be provided for. It has been usual in some mining districts, to require, that engines near an intended canal, should lift their mine-water into such canal, or high enough to be conducted into it by a feeder, as in the *Birmingham and Fazeley* canal. It will be worth considering, on a summit, where water is scarce, whether a tunnel may not be more eligible than deep-cutting, on account of large springs which would be intersected by the lower level of the former, when the deep cutting must perhaps be in porous stuff, or perhaps in dry open rock. As the summit pounds or levels of most canals are in deep cutting, through a considerable portion of their lengths, it is often attended with but little additional expense, except in the case of tunnels, to make such summit pounds one or two feet deeper in water than usual, as on the *Derby*, *Cromford*, *Manchester*, *Ashton and Oldham*, *Oxford*, and other canals, in order that such additional depth, being filled in winter or wet seasons, may act as a reservoir for drier ones: but it has not always been considered, that such deeper pounds, when filled 18 inches or 2 feet fuller than is necesssary, occasion the necessity of letting off twice that extra depth of water, over the area of a lock, each time that a vessel passes the summit; by which, such reserve of water is in a great measure dissipated before the dry season for which it was intended arrives. We should recommend, either the use of reservoirs so much above the summit level of the canal, that they may be emptied into the same, when the continuance of dry weather required it; or, if such deeper summit pounds be made, on account of their considerable length for holding water, that a lock capable of penning 18 inches or

2 feet, and of shutting very tight, should in such case be built, near each end of the summit, to be used as long as the summit water is higher than usual, but which might at other times be left open, when the water was level on each side of them.

Before we quit the subject of supplying a canal with water, we beg to mention, that it may be worth the while of the engineer, where water is to be pumped up to supply the lockage, as we have before mentioned, to design and calculate the expense of wind-machines, capable of doing the required work, and of the probable expense of their repair; and to compare the same with the cost of erection, expense in fuel, attendance and repairs of well constructed steam-engines to do the same work.

On the *erection of Aqueducts* for conveying a canal over any very deep and wide valley, or over a large or navigable river, we beg to mention, that a most secure foundation must be sought for, by sinking, or obtained by piling, for the piers of an aqueduct-bridge, and that the arches ought, in every case, to be arches of *equilibrium*, because the least settling in brick or stone bridges, by letting through the water, may prove of the most fatal consequence. The plan of an aqueduct-bridge should be curving inwards, that is, the ends should be wider than the middle, the walls should also not be upright, but battering, receding or diminishing upwards on the outside, to give greater strength and stability to the whole; the materials, if of stone or brick, and the cement, should be of the very best quality, and the work executed in the summer season only. Care should be taken that all the joints of brick or stone are worked as close as possible and thoroughly filled with cement; the slopes for the sides, and also the bottom of the canal should be made rough, that the puddle may the better adhere to them, and that it may not slip, owing to the steepness of the sides, which must be more so than in other parts of the canal, to avoid unnecessary expense of masonry or brick work in the

length of the bridge. The lining as above is, however, liable to be soon cut away by the boats.

Since the year 1795, a new kind of aqueducts has been introduced into this country, composed partly of cast-iron, which promises the greatest advantages, except, perhaps, where free stone of an excellent and durable quality is found upon or very near the spot, or where the contemplated aqueduct-bridge is very distant from any iron mines, or existing navigations that connect with such. In the year 1797, Mr. *Thomas Telford*, the engineer, wrote an account of the inland navigation of the county of Salop, which has since been printed in J. Plymley's Report to the Board of Agriculture, on the Agriculture of Shropshire, and we beg to extract therefrom what he says on this subject when speaking of the *Shrewsbury* canal, p. 299, as follows: "This canal passes over the valley of Tern, at Long, for a distance of 62 yards, upon an aqueduct made all of cast iron, excepting only the nuts and screws, which are of wrought iron; and I believe this to be the first aqueduct for the purposes of a navigable canal which has ever been composed of this metal. It has completely answered the intention, although it was foretold by some, that the effects of the different degrees of heat and cold would be such as to cause expansion and contraction of the metal, which not being equal to extend or draw back the whole mass of the aqueduct, would operate upon the separate plates of iron so as to tear off the flanches which connect the plates lengthwise, and break the joints. Others said, that the expansion of freezing water would burst the sides, and so break off the flanches which connect the sides with the bottom plates: but after the trial of a summer heat, and the very severe frost of the winter of 1796, no visible alteration has taken place, and no water passes through any of the side or bottom joints."

Mr. *Robert Fulton*, an American engineer, who happened to be in this country at the time, seems to have availed himself of what was going on at Long Aqueduct as above, and of the machinery of various kinds,

in use upon the *Ketley and Shropshire* canals, and to have prepared drawings and models of a variety of such machinery, with many improvements of his own, and submitted the same to the examination of a committee of the Board of Agriculture, in March 1796. There have since been published in a handsome quarto volume, entitled, *A Treatise on the Improvement of Canal Navigation, by R. Fulton*, from which, page 114, we beg to extract what he says on constructing aqueducts of cast-iron for a narrow canal as follows: "The butments and piers being raised, it will only be necessary to extend two pieces of timber across the span; each to be braced back to the piers, and covered with plank, to form a stage or a scaffolding which will answer every purpose of centres necessary to works of stone. The iron work, may all be cast in open sand, and of the following dimensions: supposing the span 100 feet, and the spring one sixth of the span.

First, three segments of a circle, each in three pieces, about 36 feet long, eight inches by four diameter, to be united. Second, three straight bars, to extend from one pier to the other, to be of the above diameters, may also be cast in three pieces, which bars are to extend along the top of the segments to the piers, and form a line parallel to the horizon; the bars and segments to be united by perpendicular stirrups, ten or fifteen feet distant from each other. The mortice in the lower end of the stirrup being thirteen inches long, will be sufficient to secure the segment, and leave room for a hole two inches square, through which a cross brace is to pass, and fasten the segments at proper distances; the brace to have a mortice cast on each side of the stirrup, in order to tighten the work by wedges. On the top of the stirrup, the square hole to receive the cross brace may be beneath the mortices, by which means the whole may be combined, and form an iron stage to support the troughs. The trough plates for the canal should be at least one inch thick, the side plates six feet broad, and as great a length as can conveniently be cast; which may be performed twelve feet and perhaps more

in length: the flange to be outside on those plates. The bottom plates may be six feet wide, thirteen feet long, seven feet plate, and four arms projecting, each three feet long, in order to support the horse-path and braces. Two of these plates laid across the stage, and screwed together, with the flange under, will compose a length equal to one of the side plates which may either meet or break joint as is thought proper. The whole may in this manner, be screwed together on packing of wool and tar; and have the seams pitched like those of a ship. On the plates composing one side of the trough, small brackets, about three feet from the top, must be cast, in order to support the horse-path; perpendicular rails, eight feet long, being raised from the arms of the bottom plates, will support the outside of the horse-path, as also the iron railing. By this mode, two patterns will answer for the whole of the trough-plates, and but few will be required, for the springs, rails and spurs. The saving in time and expense will be considerable; particularly where it is necessary to bring the stone by long land carriage; for the arches being dispensed with, and the piers not more than one third of the dimensions necessary to an aqueduct of stone, will most materially reduce the quantity of masonry. In aqueducts of stone, one of the great difficulties is to line and puddle so tight as to prevent the water penetrating into and injuring the masonry; but in one of iron, should a leak take place it will instantly appear; and on shutting the stop-gates at each end, and discharging the water, it may be stopped in a few hours, if not minutes: this circumstance in aqueducts is, perhaps, one of the greatest preservatives; they are consequently less liable to injury, and only subject to the corroding tooth of time."

Since the above period, a most stupendous work of this kind has been undertaken by Mr. *Jessop*, on the *Ellesmere* canal, and is now nearly or quite completed, for crossing the Dee river at Pontcysyltee, about 20 miles S. W. of Chester; where nineteen massive conical pillars of stone at fifty two feet from each other, the mid-

dlemost of which is no less than 126 feet in height, support between the top of every pair, a number of elliptical cast-iron ribs, which by means of upright and horizontal bars, sipport a cast-iron aqueduct about 987 feet long, 20 feet wide, and 6 in depth, composed of massive sheets of cast-iron, cemented and rivetted together, having on its south side an iron platform and railing for the towing-path. In May, 1776, Mr. *James Jordan* took out a patent for suspending aqueducts from ribs of cast iron above them, in the same manner as his suspended iron bridges.

Among the most considerable aqueducts of stone or brick are those at Lancaster on the *Lancaster* canal, at Kirkintolluch and at Kelvin on the *Forth and Clyde*, Chirk on the *Ellesmere*, Marple on the *Manchester, Ashton and Oldham*, Monk-bridge on the *Trent and Mersey*, Whaley-bridge on the *Peak Forest*, Avoncliff and Dundas on the *Kennet and Avon*, &c. while at Burton on *Bridgewater's*, a navigable river is passed, and near Wigan on the *Leeds and Liverpool*, another canal, (the *Lancaster*) is passed upon aqueducts.

CHAP. VI.

EMBANKMENTS. PRECAUTIONS TO PREVENT SLIPS.—ARCHES FOR BROOKS OR ROADS. THEIR CONSTRUCTION. WING-WALLS. EMBANKMENT ON THE SLOPE OF A HILL. THE MOST CONSIDERABLE EMBANKMENTS ENUMERATED. SAFETY-GATES. THEIR LOCATION AND CONSTRUCTION. STOP-GATES. STOP-PLANKS. STOP-BARS, HOW MADE. WASTE-GATES. TRUNKS. WEIRS. TUMBLING-BAYS. WEIR-BRIDGES. WELL-FALLS. PUDDLE-WEIRS. FLOOD-GATES. CULVERTS, MANNER OF MAKING THEM.

THE *making of embankments* appears to have been long practised in China, where we read of parts of their canals of 200 feet wide, that are embanked 20 feet high, for great lengths together; the rivers through the fens of Cambridge and Lincolnshire in this country, have also been long confined thus, by artificial banks.—Most of the aqueducts of which we have been speaking above, have less or greater lengths of solid mounds or embankments for forming the canal upon, to the proper height, and for joining them to the aqueduct-bridges. All the observations and remarks which we have made, respecting the setting out and ascertaining the dimensions of the head of a reservoir will apply to embankments. The angle of the slopes ought to be determined by the result of similar enquiries, and the same precautions used to prevent slips, in soils that are so disposed, as were mentioned respecting reservoir heads: it will generally be a safer way to carry up a puddle-ditch in each bank, than to trust only to lining the canal. In every considerable embankment there will be required one or more arches to convey a brook or river under the canal, and, perhaps, others for roads to pass through; such arches should always have an inverted arch turned below them, deep enough for the bottom of the brook, and below the roads, and the arch itself should

be one of *equilibration*. To avoid making a very large arch for a brook or small river, it is usual to make a road or communication arch near it, with its bottom well paved, and no higher than the surface of the meadows, which will serve to vent the sudden floods in rainy seasons.

Great care should be taken to slope off and finish the ends of arches under an embankment, agreeable to the slopes or sides of the banks thereof; by which the banks are prevented from moulding down into the brook or road-way, and aukward projections in the slopes of the banks are avoided: at the entrance or upper side of a water-arch, or of road-arches that will occasionally become such, return or wing-walls of brick or stone should be made, for some distance along the bottom of the slope of the embankment, and the sharp corners of the entrance of the arch should be a little rounded off, to prevent the rapidity of sudden floods from wearing or injuring the bank. It is to be observed, in conducting a canal along the side of a steep and high hill, that after a certain degree of steepness of the ground, it will not be possible to cut the canal on the principle that the excavation shall just form the bank, but such banks will often require stuff to be provided from other places, and such are indeed cases of embankment: and here it may be proper to advise, that new banks, ought not to be placed on very steep ground, without considerable care in first forming it into levels like steps, to prevent the slipping of the new part, as happened near Bradford on the *Kennet and Avon* canal, after all the care that was taken, and great lengths of the canal slid down into the *Avon* river below, the making of which good again cost, we are told, near 1000 pounds. Among the considerable embankments that have been made for canals, are those at Bollin and Stretford on *Bridgewater's*, and Wolverton, Weeden, and Bugbrook on the *Grand Junction*, &c. but the greatest extent of high embankment known, is that in the valley of the Boyne, in the *Grand* canal of Ireland; and the highest bank in the world is also to be found in the same canal in the valley of the Rye river;

it is above 90 feet high. We are told that Mr. *James Brindley* used a kind of caisson of planks, in forming his great embankments, in which dirt-boats were used, to bring stuff from the higher ground, that had been cut through.

We are next to speak of *safety-gates*, *stop-gates and stop-planks* which are different contrivances for stopping the water of a canal in case the banks are failing in any part, or that any part wants emptying to repair the works. Advantage is generally taken of the walls under the bridges, for constructing these contrivances, where the same happen in the proper places; otherwise the canal must be contracted by upright walls, the same as is done at the bridges on purpose for them.

For explaining the nature and construction of safety-gates, it is necessary to premise as above, that the sides or wall of the canal must be upright or perpendicular; a sill of solid oak or of stone extending across the canal, and some distance into each side or wall, is to be soundly embedded into the bottom of the canal, so that its upper surface shall be nearly level therewith; into this sill on each side of the canal is to be mortised an upright or perpendicular post of stone or of oak, extending about a foot above the top water line, and each of which posts is to be embedded into the side or wall in the most secure and substantial manner, and is to be flush with the general face of the wall; on each side of these posts, however, the wall is to have a recess of about two inches, and of sufficient extent to give room for the gates to play and shut against the posts: the gates are to be hung to each of the outer, upper edges of the sill, turning on hinges, centres or hollow quoins. These gates thus opening each way, are not to lie flat on the bottom of the canal, but to be a little raised towards a shutting position, (not so much however, as to obstruct the passage of boats) and they are to be so balanced by counter weights that they will remain in this position unless disturbed. When thus placed they will operate as follows: supposing, for instance, the canal to be made in a north and south direction, and that a sudden breach should

happen in one of its banks to the south of the safety-gates; it is evident that a current in the canal from north to south would be the immediate consequence.—This current, pressing against the under side of the inclined northern gate (the edge of which is to be sloped off to give greater effect to the water) will, at once, force it up, against the posts at its ends, in a perpendicular position; in which situation it will completely close the canal and prevent the passage of the water behind it. A breach to the north, will produce a similar effect upon the other gate. Safety-gates should be placed at proper distances on every long level, especially if the same is much embanked; both to prevent the loss of so much water, in case of a bank breaking, and the mischief that the same would do to the lands, mills, &c. below the breach. We read of a new bank breaking on the *Warwick and Birmingham* canal, and destroying a gentleman's park-walls; and in the year 1783 so great a breach suddenly happened on *Bridgewater's* canal, near London bridge on the Chester road, that three barges were carried through the same a great way out into the fields. A *single* safety-gate ought to be placed at the end of every long embankment, to stop the water in case of a breach happening in its banks.

Stop-gates are similar in their construction to the safety-gates above described, except that the gate lies flat on the bottom of the canal, instead of being balanced, and has a chain by which it can be hauled up, whenever occasion may require the canal to be stopped.

Stop-planks are a simple, though not so expeditious, a provision for stopping the canal as the last; a groove is provided in the two opposite walls under a bridge, or in a narrow and walled place, and a sufficient number of well jointed planks are provided, to be dropped into the groove whenever the water is required to be stopped, and here these are often called *drop-planks*.

In very large works like the *London docks*, a barge or vessel is built in the place whose head and stern posts exactly fit into a groove as above, and the vessel can be floated into and out of its place or sunk therein as occa-

sion may require. The engineer will have to make provision, while the canal is digging, for stop-bars at the several intended toll-houses, or other places where it may be necessary to stop barges in the night, or in cases of any dispute about their lading: these bars are composed of a large baulk of fir timber floating on the water; and a small arch capable of containing such a floating beam of the proper length is provided under the bank, so that when the trade on the canal is required to be stopped, the toll-clerk has only to draw out the beam by means of a cord attached to it, until its end enters a recess in the opposite wall, and then to lock the beam fast.

We shall next describe the *Waste-gates*, *Trunks*, *Tumbling-bays*, or *Weirs*, that must be provided, for letting off the superfluous water of a canal in wet times, for keeping the water at one certain height, or drawing it off in case any repairs are wanting. *Waste-gates* are sluices of the common construction in the side of a canal, where any considerable quantity of water is required to be let out, and are to be drawn up, either by a rack and pinion, a chain and roller, or a number of holes for a crow-bar, as circumstances may render most eligible: where lesser quantities of water are to be let out, or for emptying certain lengths of the canal between the stop-gates or planks, when occasion may require, *Trunks* formed of oak or elm planks, well jointed, should be laid into the bank, at the bottom of the canal, and carefully inclosed in puddle, with a valve or shuttle that will shut very tight, and can be readily drawn when the water is required to be let off: we beg to recommend, wherever wooden trunks are used for any such purpose, that they should be sunk so low, or the mouth where they discharge should be made up, so that the trunk may always remain quite full of water, and the air at all times be excluded; in which situation wood will last much longer than if wet and dry alternately.

In the choice of situations for *Weirs*, to discharge the surplus water of a canal, care must be taken not to let off any considerable quantity at any time, except in-

to a brook-course or bottom of a vale, that is crossed or proceeds up to the canal, and has ditches through which the water can escape, without tearing or doing injury to the adjoining land. The most frequent *tumbling-bays* or *weirs* to discharge water from canals are composed of strong walls of brick or masonry, whose top is coped with hewn and well jointed stone, or with a stout sill of oak, the top of which is just level with the top-water line, or about one foot lower than the top bank. There should be a paving of large stones for the water to fall on, and escape at, and wing-walls at the ends of the *weir*, to keep up the bank and confine the water. These weirs are generally on the towing-path side, on which a low plank bridge is supported over it, called a weir-bridge. When these weirs are wanted of considerable length, the wall which composes them ought not to be straight but on a circular plan, curving inwards in the middle, by which it will be better able to support the lateral pressure of the bank behind it; a puddle-ditch should be carried up immediately behind the wall, allowing the courses of puddle to set thoroughly, before others are applied, that the great pressure of the semi-fluid puddle may not overset or disturb the wall, and the paving, on which the water is to fall, should be of large and well jointed stones, and if set upon a course of puddle it would be a further security against their washing up, which too often happens We have seldom seen any considerable weirs or tumbling-bays of the above construction, but where it would have been better to have followed the example of Mr. *James Brindley* on *Bridgewater's* canal, and have made a *circular-weir* or well-fall, on the upper side of the canal. We have spoken of well-falls when treating of reservoirs.

For letting a proper quantity of the surplus water of a canal forwards into the pounds below, a small weir is generally constructed in the walls at the head of each lock, which lets the water down into the puddle-holes, or crooked arches that convey the water for filling the locks, and hence such are called *puddle-weirs* or lock-weirs. The upper gates or doors of the locks are often

planked up no higher than the top-water line, and therefore serve as weirs for discharging the surplus water into the lock; and gates of this sort are called *flood-gates*.

On the *construction of Culverts*, or drains under a canal for conveying away water from the upper to the lower side of the canal, it remains for us to say, that they should be carefully proportioned in size to the stream that is to pass through them in floods, and should be constructed of sound brick or stone work, and inclosed, or at least well covered on their upper side with puddle. Many engineers have used wooden trunks for this purpose, but except wood be in great plenty, and of the best quality, and good brick or stone very difficult to be procured, it is not advisable to use perishable materials in such situations. If the ground be moory or bad, and a culvert must lie pretty near to the bottom of the canal, and have but a slight covering, it may be proper, in some situations, to use cast iron cylinders flanched together, as was done under or near the *Staffordshire and Worcester* canal; and such may be made cheaper and easier of carriage, by being in two or three segments longitudinally, to be flanched together before they are laid down; and in such situations, perhaps leaden rivets might be cheaper and more durable than wrought iron ones, or nuts and screws. If bricks are to be used in culverts, over soft and moory ground, or quick-sands, a cradle composed of ribs of wood and boards or rails, such as are used for centering, should be prepared, suitable to the outer curve of the intended culvert, and such cradle should be carefully embedded, in the proper place to receive the bricks of the lower segments of the culvert: for want of such precaution many a culvert has sunk partially, perhaps owing to the springs excavating the sand or filth from below, and has been broken, to the great injury of the canal. Culverts are of so much importance, that too much care can hardly be taken to make them solid and secure, and to cover them effectually with puddle: another hint we would here give, respecting the choice of places for the culverts; they should never, if possible to avoid it, be made ex-

actly in an old brook-course, ditch, or slough, but in the nearest sound ground; and where often they can be got down to the proper depth, without any trouble from water, or at least the same can be easily pumped out; and the stream need not be admitted to the work, until the old brook or slough is required to be filled up. In this way it will often happen, that culverts may remain during the winter following their construction, completely excluded from the frost, and therefore may be done later in the year, by filling in the stuff upon them and at their ends, and the mortar be completely set before the new channel at the ends for conducting the water through them need to be cut. And we beg to remark that by an attention to this circumstance in making new arches under roads, and keeping the bottom of the arch much lower than is generally done, or indeed practicable in the old channel or slough, half or two thirds of the whole expense will generally be saved; for a deep and new channel being cut to the new arch; by scouring out the brook-course for some distance below, old ford-places, if the descent to them be easy and convenient, will not require immediately to be filled up or altered; but during any extraordinary flood, the same, if composed of gravel and hard stuff, may act the part of a wier for a short time, in carrying off the water, without injury to the road or material inconvenience to the passengers. It will sometimes happen, that a stream of water is required to pass under the canal, in places where it is not embanked; in such cases a crooked or *broken-back culvert* is to be made for the purpose; this will require puddling as before described, and a strong box full of holes, or grating should be fixed over each of its ends, as well as pits or holes to be made at the upper end, deeper than the mouth of the culvert; to receive and detain the sand and gravel which the stream may bring down in hasty rains, otherwise these, or the stones that mischievous boys might throw into it, would in time choak it up in its lowest place under the middle of the canal.

CHAP. VII.

TUNNELS. SELECTION OF A PROPER PLACE FOR A TUNNEL. HEADING OR SOUGH. CROSS-HEADINGS. TUNNEL-LINE. TUNNEL-PITS OR SHAFTS. HORSE-GIN OR TURN-BEAMS. TRANSFER OF THE LEVEL. CENTERINGS FOR THE ARCH. EXCAVATION. TEMPLETS. PARTICULARS OF THE TUNNEL AT BLISWORTH. FOULRIDGE TUNNEL. ENUMERATION OF THE PRINCIPAL TUNNEL.

THE *construction of Tunnels*, or subterraneous arches, for drawing off or conveying of water, has been known from the earliest periods, as appears by the celebrated works of this kind between lake Copias in Bœotia and the sea; between the lakes formed by the inundations of the Nile in Egypt and the Mediterranean; as also by the courses of the Roman aqueducts, many of which were tunnelled through hills of great extent. In the mining districts of this country, we have long had levels or audits of considerable extent to mines; in the neighbourhood of Matlock in Derbyshire, the *Helcarr Sough* has been cut through the solid rock for nearly four miles in length, for the purpose of draining the several lead mines in the vicinity; *Wirksworth Moor Sough*, of near three miles long, and *Cromford Sough* of two miles in length, with many others of less note, are also to be found at great depths in that neighborhood. The first *tunnel* that we read of, as constructed for the purpose of navigation, was by Mr. *Riquet* near Bezieres on the *Languedoc* canal in France; and the first in this country, was the entrance made to the Duke of *Bridgwater's* coal-mines at Worsley near Manchester by *James Brindley*; while the first of our tunnels undertaken for the purposes of general trade, or as a thoroughfare, was by the same engineer at Harecastle on the *Trent and Mersey* canal.

It is essential to the convenience as well as the beauty of a tunnel, that the arch thereof should be quite straight, and exactly level; considerable care will therefore be necessary in obtaining an exact section, by levelling, of the hill that is to be perforated, when a line in the exact vertical plane of the tunnel is fixed and staked out over the hill; in doing which, it will be right to choose the narrowest place that the hill presents at the proposed level, and where also the hill rises rather boldly from such level; otherwise an expensive and troublesome length of deep-cutting would be necessary, or of the tunnel that must be dug out from above and then covered up again, before a sufficient depth of stuff over head would be come at, to admit of working under ground; it will also be of consequence, when determining the exact line for a tunnel, to avoid having the deep-cutting and entrances in alluvial or disturbed and slippery soils, but, if possible, to enter at once upon the solid and undisturbed *strata* of which the hill is composed.

It will but very rarely happen, and that only in short tunnels, made for the purpose of preserving the level of a canal, that the workings will not be in soil more or less full of springs of water; therefore one of the first operations, after the line and level of a tunnel is finally determined on, is to search, by levelling, for a place in the nearest vale or brook that is some feet below the proposed level of the bottom of the tunnel; this must be more or less, according as the intended tunnel is of greater or less length; and from this point a large ditch must be opened, with a very small rise towards the end of the tunnel, as far as is practicable, and then a *heading* or sough must be begun, just large enough for men who are used to such business to work in, and to line it securely with bricks as they proceed, but leaving proper openings in the joints for the springs to collect freely from all sides into their heading. Some persons have supported their headings with boards and props of wood, instead of arching them; but which practice we cannot recommend: all such works ought to be dura-

bly constructed, or should any accident or circumstances, as the want of money, &c. delay the completion of the work for some years, all this tedious and expensive work will perhaps require doing again; it ought also to be considered, that after some years or ages have elapsed, the tunnel may want repairs or alterations, and that the same headings may be again opened and used, to lay it dry in a short time if durably constructed; which may be of the most material consequence in lessening the period of interruption to the trade by such repairs or alterations. It will be necessary to begin a heading as above mentioned on each side of the hill, and work them up towards each end of the tunnel, along the line of which it is to proceed from each end, rising gently as it advances towards the middle point, that the water may run off freely; the headings should be a few feet below the bottom of the working, that will be necessary for the inverted arch of the tunnel, and a few yards off on the side of it; and cross headings or soughs must, at stated distances, be run under the line of the tunnel, into which openings can afterwards be made to carry off the water which collects in each separate working. If the soil be rather stiff, and the quantity of water in it not very considerable, one heading may suffice; but where porous stuff, with great quantities of water are intersected, it will be necessary to branch off an additional heading, to proceed along the other side of the line, the more effectually to draw off the water; by which perhaps, if the headings are done a sufficient length of time before the tunneling is begun, a quick-sand, or similar running of the stuff, may in several places be prevented. If in driving the headings, any fissures or cavities filled with sand or loose matters, are intersected, and are found to bring a considerable quantity of water from one side of the line, it may be right to drive a cross heading for some distance into such porous stuff, for intercepting the water before it reaches the intended workings of the tunnel.

The next operation will be to set out a line very truly parallel to the line of the intended tunnel, and to mark

thereon, at equal distances, about 150 yards apart, or oftener, if great expedition in completing the tunnel is required, the place of the several tunnel pits, that are to be sunk for drawing up the stuff excavated from the tunnel, and letting down the centres, bricks and other things wanted in the work; it will be well to contrive the line of the headings and tunnel-pits, so that they may coincide; and in great lengths of heading, shafts or tunnel-pits may be sunk at intervals, to give air to the headings, and through which the stuff excavated therefrom may more readily be drawn up: and it may be advisable in some instances, to set out a line on each side of the tunnel, for the tunnel-pits, to be some on one side and some on the other of the tunnel, and that both may in places intersect the headings. If bricks or stones are not at hand when the tunnel pits are begun, and wood is plenty, the shafts or tunnel-pits may be made square, and have their sides supported by boards and struts of wood; otherwise they should be made round and lined or steined like a well as soon as they are done; if the soil should prove loose and full of water, it will be necessary to stein the shaft as soon as such soil is reached, and to work afterwards from underneath the curb, and let the steining sink, as is done in well sinking. Some tunnel-pits have been made over the line of the tunnel, but such do not admit of being steined with safety, on account of the weight thereof, which would damage the crown of the tunnel, where they were grained into each other; and such of them as are left afterwards for air shafts, if the soil is wet, will let an unpleasant dripping of water down upon the goods or passengers in passing through the tunnel, as we once experienced in passing through Braunston tunnel on the *Grand Junction* canal. A common roll and winch will be sufficient for drawing up the stuff and water, and letting down bricks to stein with, unless the quantity of water is considerable; but it will be proper to erect a horse gin, or turn beam, such as are used at the shafts of coal-pits, for the cheaper and more expeditious drawing up the stuff and letting down of materials, when the workings have commenced.—

We have before recommended a line to be staked out exactly parallel to the line of the tunnel for the centres of the several tunnel-pits, and care should be taken that no gin, or other obstruction, be erected in this line, so that a fine line or string can at any time be stretched across the top of any of the tunnel-pits, and be adjusted without fear of mistake in the exact range of this line, or parallel to the intended tunnel. When a tunnel-pit is completed and steined, and a communication formed with the heading to keep the same clear of water; two points must be fixed in the steining near its bottom, by letting fall or suspending plumb-lines, at the time that there is no wind to disturb their verticality, and adjusting another fine line between the two points on the steining below, so as to be exactly under and parallel to the line above and consequently so to the intended tunnel. The engineer should carefully repeat his levels and transfer the level of the bottom of the intended tunnel, or the surface of the water of the canal therein, and mark the same carefully in the steining of each tunnel-pit: and thus the workmen who are to undertake the work will be furnished with the direction, level, and distance of the tunnel they are to form under ground.

The work commences, by excavating a passage from the tunnel pit into the line of the intended tunnel, and supporting the same properly with timber, or walls and an arch as a passage into the work. A piece of the intended tunnel, a yard or more in length, according as the soil is found to stand, is then excavated, in the proper form, place, and level, ascertained from time to time by stretching a fine line between the marks, on the steining before mentioned, and measuring therefrom, and using a common plummet-level for transferring the level from the level-mark on the steining before mentioned; great numbers of ribs for centerings should be prepared in different segments, and in readiness to put together with nuts and screws, leaving as much room in the middle or centre as can conveniently be done, for the men to work and pass through after the same are put up; the parts of two of these ribs are then to be let

down the tunnel-pit, and to be put together and fixed up in their proper place and distance asunder in the tunnel; short lengths of boards or laths are to be prepared and fixed on their outsides, as the turning of the arch proceeds; which, as well as every other part of this very difficult work requires the utmost care and experience to make it sound and substantial; when this first yard or less in length of the tunnel is turned and securely keyed up, the same is secured by ramming in clay, or proper stuff, so as to fill every cavity above or withoutside the brick-work. The workmen then begin at each end of the piece that is turned, one party working one way along the line of the tunnel, and another the contrary way, until another yard or other length of the tunnel is excavated, when other ribs are put up and fixed together, boarded, and the brick work is turned round or behind, the same as before; the utmost care being taken to joint these courses evenly and securely into the former ones: the vacant space is then rammed up with earth, and a new excavation proceeded with at each end as before. The engineer ought frequently to renew his level marks from fixed and good bench marks on the ground, and to examine and adjust the ranging line, and also himself most carefully inspect each working of the tunnel, and examine, by stretching a fine line along its centre, and measuring and levelling to his ranging line in the tunnel-pit, to see that every part of the work is proceeding exactly in the same line, and so that when in process of time each adjacent working shall be joined, and the tunnel be completed, the whole may form one exact and truly straight arch. If the ground proves loose and bad for standing, it will be proper to continue the work, by different sets of men, without any intermission; and care should be taken that the work never is left, even for a night, without templets, or short pieces of plank, being put up to cover the roof, that is necessarily left open to admit the men's heads and arms, while they are turning and backing up their last length of work at the crown; and these templets should be securely shored up by spars or struts, to prevent the earth

from settling or falling in, which has actually happened in some tunnels, owing to the neglect of this simple and necessary operation, so that a considerable length of the tunnel required to be dug out from the surface of the ground to repair the breach. When the tunnel and ends are completed, ditches are to be dug out, across the headings, near the entrances of the tunnel, and a substantial puddle-ditch carried up, to effectually dam them up, and force the water that afterwards collects in them to rise up into the tunnel, through cross-headings to be left for that purpose.

The tunnel at Blisworth, on the *Grand Junction* canal being the latest that has been completed (February, 1805,) we have ascertained the following particulars relating to it, in order to give some idea of the present state and expenses of tunnel making. The internal width of this tunnel is 16 1-2 feet, the depth below the water-line to the inverted arch 7 feet, and the sofit or crown of the arch is 11 feet above the same line. The side-walls are the segments of a circle of 20 feet radius, the top arch of one of 8 feet radius. The side and top walls are 17 inches or two bricks thick, and the bottom or inverted arch 13 inches or 1 1-2 brick thick; every fifth course of the top arch, and every eleventh of the side walls, is composed of two heading bricks, or wedge-like, one inch thick on the inside and three at the back; also, every fifth and eleventh course as above (but between the courses of heading bricks) are composed of bricks laid obliquely across the others, the front and back corners being cut off for that purpose in the making, for more effectually breaking the joints, of work obliged to be done in such short lengths. The mortar that was used, was composed of one bushel of Southam lime (*blue lias*) and three of good sand. Six inches under the water-line, on each side of the tunnel, slide-rails of fir, 5 inches square, to keep the barges off the walls, are fixed by pieces of oak let into the wall below them; which rails project 9 inches from the wall, and have at every 9 feet a chock of wood upon the rail, for the bargemen to set their pole against for shoving their barges

along. We were told that this tunnel was contracted for at £15 13s. per yard run: the soil principally a hard blue clay, with two or three thin rocks in it. Sufficient headings had been executed several years before at the company's expense. The same contractors were paid 10 1-2 d. per cubic yard for excavating the deep-cutting at one end of this tunnel, and 11d. per cubic yard for the other. The expense of driving the above headings were, we understood, from 36s. to 42s. 6d. per yard run. Nineteen tunnel pits, some of them 60 feet deep, were sunk for the use of the above tunnel, which cost about 30 s per yard in depth including steining. In our inquiries respecting Braunston tunnel, on the same canal, we were told, that 320 yards of the same was drove in quick-sands, and that cost £4800 extra on that account. The Foulridge tunnel on the *Leeds and Liverpool* canal, of 1630 yards long, proved to be in such very loose and bad ground, that the whole of it, but about 700 yards was obliged to be dug out from above; in some parts 30 yards wide at top, and near 20 yards, deep, and immense works of timber were necessary to support and keep the banks apart, while the tunnel was turned, and the soil filled in again. Some part of this work done about the year 1794, cost £24 or more per yard run.

After a good length of the tunnel has been completed and well backed up, and been allowed some days or weeks for the earth to have regularly settled upon the brick-work, the centering may be removed, by loosening the screws and taking it to pieces, to be again put up and used further on in the same working. In tunnels upon high levels in porous soils, and in others sometimes near their ends, or in crossing any dry and porous stratum, it may be necessary to excavate the bottom a foot or 18 inches deeper than usual, and to fill the same up again with well wrought and stiffish puddle, and to turn the inverted arch, and as much of the sides as are below the water line, upon the same when set. The navigation through some of our tunnels is very inconvenient, owing to the want of a towing-path through them. The tunnel near Atcham on the *Shrewsbury*

canal, though of 970 yards in length, has a towing-path through it; so has one at Newbold on the *Oxford* canal, and many other short ones in different places. In all short tunnels, and even in long ones, if the ground proves, on examination, sound and good for tunnelling, it certainly would be worth while to give the necessary width to the arch, to admit of this essential appendage.

Among the most considerable tunnels that we have, are those at Worsley on *Bridgewater's* canal 18* miles in length! Marsden on the *Huddersfield*, 5280 yards; Sapperton on the *Thames and Severn*, 4300 yards; Pensax on the *Leominster and Kington*, 3850 yards; Laplat on the *Dudley*, 3776 yards; Blisworth on the *Grand Junction*, 3080 yards; Ripley on the *Cromford*, 3000 yards; Dudley on the *Dudley*, 2926 yards; Harecastle on the *Trent and Mersey*, 2888 yards; Norwood on the *Chesterfield*, 2850 yards; West Heath on the *Worcester and Birmingham*, 2700 yards; Morwelham on the *Tavistock*, 2500 yards; Oxenhall on the *Hereford and Gloucester*, 2192 yards; Braunston on the *Grand Junction* 2045 yards, &c.

The longest tunnels that have been proposed, besides the above, were one of five miles on the once proposed extension of the *Manchester, Bolton and Bury* to the Calder river; and one of 4 1-4 miles on the *Portsmouth and Croydon*, through the Chalk hills south of the latter place. The towns of Manchester, Kidderminster, and Southampton appear to be tunnelled under by the *Bridgewaters, Stafford and Worcester*, and *Southampton and Salisbury* canals respectively.

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* This it is believed, is a mistake. *Phillips* in his *Inland Navigation*, p. 89. when speaking of this canal, observes.—"The canal runs through a hill, by a subterraneous passage, big enough for the admission of long flat bottomed boats, which are towed by hand rails on each side, near three quarters of a mile under ground to the coal works. There the passage divides into two channels, one of which goes 500 yards to the right, and the other as many to the left, and both may be continued at pleasure." The whole length of this canal, from Worsley Mill to Manchester, is, according to Mr. *Phillips*, but nine miles.

CHAP. VIII.

DEEP-CUTTING. HEADINGS TO DRAIN OFF THE WATER. PUMPS OR STEAM-ENGINE FOR THE SAME PURPOSE. SLIPS. SLOPES OF THE BANKS. LAYING OUT THE WORK. EXCAVATING MACHINES. PRINCIPAL DEEP-CUTTINGS ENUMERATED.

THE excavating of deep-cuttings appears to have been long familiar to the Chinese, since we read of some of their canals that are in places excavated 80 feet deep! and of others that are cut 20 feet deep for seven or eight miles in length.

The setting out and determining upon the slopes of a *deep-cutting* of considerable depth and length, are objects deserving more of the engineer's attention, than has in too many instances been bestowed upon them: the first step, after the line and the level of the intended canal are determined upon, should be to examine minutely the soil in every part that is to be cut in, and to prove the same by the sinking of several shafts; if any of these, towards the centre of the hill, should be found in loose and porous soil full of water, while the ends of the intended cutting may appear to be in sound stuff; it will be worth while, in some such cases, to put down pumps and erect a temporary steam engine, to pump up the water during the work, and to drive headings from such pump-shaft, on one or both sides of the intended cutting, and below its bottom, as has been before mentioned, preparatory to driving a tunnel. Should the whole of the cutting appear to be in loose alluvial stuff, full of water and disposed to slip, or a part only of the ground at one end, as happened at the south end of the deep-cutting near Tring, on the *Grand Junction* canal, it will be right to begin such part by driving a heading up from a proper point below the intended cutting, and to give time for the springs to drain off before the cutting is begun, which may afterwards proceed

in separate lengths at the same time, and with much greater certainty and dispatch, by the help of cross headings, to drain off the water, than is practicable without such precaution, unless expensive and very powerful pumps or machines are used in the works to clear them of water in different places; while the tendency to slip is much increased by such sudden and partial drawing off the water.

Slips are among the most formidable accidents to which canal works are liable, and can hardly be too much guarded against, by giving an extra slope to banks in such places, but particularly by driving headings behind such parts, sometime before the workings are begun, in order that the springs may be intercepted, by which the most porous and loose stuff like quick-sands may, in many instances, be converted to sound and good standing stuff. After all, where the *strata* alternate very fast, and have a considerable dip, and any slippery matter like fuller's earth or potter's clay intervene, adjoining to a porous soil that can supply it with moisture, it is almost impossible to avoid slips, that will prove most disastrous in their consequences, both in expense and delay of the works; as happened at Tring deep-cutting above mentioned, also on the *Gloucester and Berkley* canal, and many others.

When the engineer has by a thorough investigation, as above recommended, ascertained the nature of the ground, and its tendency to slip, he can determine what slope the banks ought to have, in every part, above the canal; for these ought not to be regulated by the slopes against which the water is to lie, but they may be as steep as the ground or rock will stand in every considerable length together: and the degree of the upper slopes will be liable to vary accordingly; if these are too much sloped, a waste of land and labor in excavating and making spoil-banks will be occasioned, while if they are made too steep in slippery or loose wet ground, slips may happen that will occasion still more serious expenses and delay also. All these preliminaries being settled, and the width in every part calculat-

ed, a number of slope holes must be made on each side of the part to be excavated, and lock-spits dug out by a careful workman, as mentioned before in the marking out of the canal, and the top-soil being removed and clamped, from a sufficient space for stowing the stuff, the work will then be ready for the contractors to begin digging. It may not be improper, here, to remark, that in cases of deep-cutting it will generally be found useful and proper, to make provision for a bench, berm, or horizontal recess into the bank at a proper distance above the top-water line, which will serve to catch and retain the dirt that may moulder down from above, and prevent its falling into the canal. This need not be done on the towing-path side, as the towing-path answers the same purpose. This bench or berm will also be found equally useful on the upper side of the canal, where it passes along the slope or side of very steep ground.

This will be a proper place to notice several machines, and contrivances for assisting the operation of excavating canals, docks, or other deep-cuttings. The most simple and usual method for small depths is by runs of wheeling-planks, supported in an oblique direction up the side of the bank upon horsing blocks of different heights, on which the laborers wheel out the stuff. In larger works, *turn-beams*, or *horse-gins* are erected on the bank, and a level stage or scaffolding is erected over part of the deep-cutting; two ropes wind and unwind contrary ways off the drum or barrel of the gin, and pass over pulleys fixed over the end of the stage; these ropes terminate in three smaller ones, two of which have at their ends rings, and the other a hook of iron. When a loaded barrow arrives on the run below the stage, a laborer stands ready to slip one of the rings on to each of the handles of the barrow, and to hook the other end into the fellies of the wheel; when the revolution of the gin draws up the loaded barrow to the stage above, which a laborer lands, unhooks the three ropes, and affixes them in like manner to an empty barrow that is to be let down, while a full one is ascending

as before, by the other rope. The loaded barrows are wheeled away upon the stage, and run therefrom to any place above that is desired.

At the *London Docks*, we saw a very simple method used; two strong posts were set fast into the top of the bank of the docks, at 40 or 50 yards from each other; and at about five or six feet high on each, a large common pulley or ship's block was fastened, by a short length of rope; through these blocks a strong rope was run, whose ends terminated in two smaller ones, with rings at their ends, as before mentioned: the length of this rope was so adapted, that one end reached to the bottom of a very steep run or plane of planks that were laid and fixed on the bank, pointing up to the post at top; while the other end was nearly at the top of another similar plane at the other post. At a proper place between the two pullies, the whipple-tree of a horse's harness was attached or lashed on to the rope. The operation was conducted by a man arriving at the bottom of the plane with his loaded barrow, the wheel standing at the foot of the plane, the end of the rope being at the bottom of the plane, and the horse standing still near the post at its top; the laborer then slipped the two rings on to the handles of his barrow, and the horse being set in motion towards the other post, the barrow was drawn up the plane, and the man also with it, who made use of his feet, sustaining himself from falling backwards by holding fast by the barrow handles, which he at the same time was enabled to guide; when arrived at the top, and entered upon a plane there of less inclination, the horse had arrived almost at the other post; and while he was stopped, and was turned round ready to return again, by the boy who attended him, the laborer slipped the rings off his barrow handles, and wheeled the same away upon the upper run; another laborer instantly slipped these rings on to the handles of his empty returning barrow, and the return of the horse let him and his barrow down the plane again, the handles going first, and the man holding them as before, but with his back to the barrow; while the other

ends of the rope were drawing another laborer and his loaded barrow up the other plane as before. The simplicity, dispatch, and perfect operation of this contrivance, do great credit to its inventor. In very considerable works, it will be attended with the greatest dispatch, as well as ultimate saving of expense, to use trams and temporary iron rail ways; and if the height and quantity of stuff to be delivered at any one place be very considerable, inclined planes, with steam-engines of small dimensions, (such as are now every day manufactured and improved) should also be erected, to draw up the trams, as at the *London Docks* above mentioned. It is evident, that the simple and straight course for the horse, attached to the middle of a rope, as above, may often be substituted for the expensive turn-beams above mentioned, particularly where dispatch in setting the apparatus to work is an object.

Among the most considerable deep-cuttings, are those at Ashton, on the *Lancaster*, Tring on the *Grand Junction*, Coston Hacket on *Worcester and Birmingham*, Burbage on the *Kennet and Avor*, Littleborough, on the *Rochdale*, Smethwick on the old *Birmingham*, &c.

CHAP. IX.

DESCRIPTION OF A LOCK OR POUND-LOCK AND OF ITS USE CHAMBER OF THE LOCK. GATES, PADDLES OR CLOUGHS, BREAST OF THE LOCK. CONSTRUCTION OF A LOCK. DOVE TAIL PILES OR PILE PLANKS DESCRIBED. SHEETING. LOCK-SILL RETURN-WALLS OR WING-WALLS. HOLLOW QUOINS, CROOKED CULVERTS WEIR OR OVER-FALL DESCRIPTION OF THE GATES. BUMPING PIECES. STRAPPING POSTS. COFFER-DAMS.

A *LOCK* or *Pound-Lock*, is the connecting part between the two pounds or reaches of a canal that are upon different levels, and this part, called the

chamber of the lock, can at pleasure, be made to coincide, in the level of its water, with either the upper or lower canal. This is managed by means of two pair of doors or gates, one at each end of the chamber of the lock, in which gates, or through the side walls of the chamber, are provided small sluices, or paddles, by which water can be let from the higher pound to fill the chamber to the upper level, the lower gates being close shut; or to empty the same to the level of the lower canal, the upper gates being close shut: by which means, supposing the lock *emptying* (this term is often used, but it is not to be literally understood, since the lock, when said to be empty, has the same depth of water in its bottom as the lower canal has), and a vessel or boat arrived on the lower canal, there will be no difficulty in opening the lower gates, and entering the lock, because the water is level and at rest; having entered the lock, the gates are shut after it, and water is drawn from the upper canal by the paddles or cloughs, and in a few minutes the lock becomes full, the boat having risen with the water; when this is the case, the upper gates can be opened without difficulty, the pressure of the water being equal on both sides of them, and the boat can now move forwards on the upper canal. In this state of the lock, we have only to suppose another boat to enter from above, and to shut the upper gates after it; when the upper paddles being close shut down, and the lower ones opened, the water will sink in the chamber, and the boat with it, until the lower gates can be opened, owing to the level of the water, and the boat can proceed forwards on the lower canal. The two operations which we have described are called *locking up* and *locking down*.

We have before observed, that the fall at each lock ought to be equal; and the locks ought to be all of one width and length, unless water be in great plenty, and any local trade of a particular kind may require them to be otherwise; because, when the locks are all equal in size, a boat in descending through a line of locks will require the same quantity of water at each lock, which

we may suppose to descend with the boat, and there will be no water to discharge uselessly by the weirs, or required from the feeders, by such boat during its descent, as must happen in descending through a series of unequal locks.

The upper gates of a lock stand on a weir, or wall made across the canal called the breast of the lock, and the place of this is to be fixed by the engineer before the workmen can begin to dig out the ground for the lock; which being done, an inverted arch, with a slight curvature, is turned very sound with bricks or good hewn stones, as a floor to the chamber of the lock, which, if the soil is porous, should have a lining of puddle under it, and should be worked into the side and breast walls: the foundation of these walls ought very carefully to be attended to, and if the ground is not very sound and good; piles must be drove, and the foundations of them secured in the most substantial manner. Instead of turning an inverted arch under, and for some distance within and without the lower gates, two rows, or more, if the soil is very porous or soft, of pile-planking, or dove-tail pikes, are to be drove across the bottom of the lock; the length that these are to enter into the ground will, in a great measure, depend on the softness and porosity of the bottom. *Pile-Planks*, or dove-tail piles, are stout pieces of narrow elm or oak planks, each having a groove down both its sides to receive a thin slip of deal or other straight-grained wood, to break the joint, and prevent the water from getting through; before the first pile is drove, it is to be sharpened at bottom by a level on each side, and shod with iron, if that precaution shall appear necessary; the other pile-planks that are drove in succession, are sharpened to a double wedge, but instead of the acute angle being square to the pile, it is levelled to about 45°, by which the second pile, as it is drove, will be forced close to the first, the third to the second, the fourth to the third, &c.; and the slips or tongues being afterwards put down the grooves an impenetrable barrier will be formed to prevent the water from soaking and softening the

foundation, and at length undermining and blowing up the lock-gates and walls. The heads of the pile-planks should be sawed off very smooth and true after they are drove, and a cross-bearer or sleeper is to be nicely fitted to them and firmly spiked down: other intermediate and parallel sleepers are to be fixed down upon the heads of bearing-piles drove for that purpose, and the whole is to be covered, after the intermediate spaces are closely filled up with bricks and cement, by very sound and nicely jointed planks, that are called the *sheeting* of the lower gates. Upon this sheeting the lock-sill is to be fitted and strongly fixed down; if the canal is wide, or the fall of the lock considerable, this ought to be composed of two pieces of oak timber, each abutting against the hollow quoins at one end, and meeting at the other in an angle towards the head of the lock, whence such are often called mitre-sills. A similar precaution is to be used on the breast of the lock, by driving a row or more of good long pile-planks, with cross pieces or sleepers, and sheeting for the upper gates on which the lock-sills are to be laid; as also a stout piece of wood, cut to the curve of the breast-wall of the lock, to which it is to act as a coping, to prevent the keels or stems of the boats from damaging the same. It is usual to set out the foundations of the lock-walls straight and parallel to each other, (excepting the wing-walls or return-walls at the end to keep up the earth, and connect with the sloping banks, in the upper and lower canals) and when these walls are arrived at the height of the floor of the chamber, and sheeting of the lower gates, then to begin to batter or slope them back to give them greater strength. On the *Derby* canal we found the locks 90 feet long between the gates; the bottom line of the foundations straight, and exactly 14 1-2 feet apart; as the walls rise they are gradually battered between the gates to 15 feet apart; and in the middle between the gates to 15 1-2 feet, so that the coping of the walls of the chamber of the lock are curved three inches towards the back: and all the best modern locks are constructed on similar principles. Hollow

quoins which are large hewn stones, having a regular curved space cut out of one of their angles, are worked into the walls for the gates to turn in, instead of hinges: if good durable free stone is difficult to be procured, the hollow quoins may be composed of very large bricks made in proper moulds for the purpose; and in large works, a large piece of cast iron of the proper shape to work into the wall, is sometimes used instead of quoin-stones or bricks, as at the *London Docks*. The tops of all the walls, locks, bridges, or other erections of a canal, ought to be coped with hewn and well jointed stones, and cramped together; or with large and well burnt bricks of the proper shape, having their top angles rounded off, and set in good cement. Proper buttresses of good masonry should be made to the walls of the lock behind, to give them greater strength, and to tie them more effectually into the bank, and to break the regularity behind, so that if water should leak through walls in any particular part, when the locks are filled, or allowed to stand full longer than is proper, such water may not connect together in a large extended sheet, to act by its hydrostatic pressure in overturning or bulging in the walls, of which we have read and seen so many instances. A proper space behind all the walls should be puddled, allowing each course to set effectually before another is applied; and provision must be made in carrying up the walls, for crooked culverts, each of 14 to 20 inches or more in diameter, according to the supply of water and dimensions of the lock, called the puddle-holes, to extend from near the floor of the chamber of the lock, behind the walls, and rising up, so as to return into the lock again behind or above the upper gates. A recess is made in each wall above the several hollow quoins, large and deep enough for the gates to open back into, and remain out of danger from barges passing, into or out of the lock. In the recesses belonging to the upper gates, a weir or over-fall for the water is provided, four or five feet long, having a coping or sill of good stones or bricks, just the height at which the water is intended to stand in the upper

pound or canal ; these are called the *puddle-weirs* or *lock-weirs ;* a large flat stone is usually laid over these, leaving three or four inches in height for the stream of water, to complete the wall upon, and the cavity is conducted down, diminishing in width and enlarging in depth behind the walls of the lock, into the puddle-hole, or crooked culvert before mentioned.

The construction of the puddle-holes and weirs deserves the particular attention of the engineer, to see that they are constructed of the very best bricks, laid in good cement, and the same allowed to set thoroughly before the canal is filled ; or the rapidity, and frequent action of the water in these parts, will wear, undermine, and endanger this part of the lock.

We may proceed now to describe the other appendages of the lock ; these are the lower gates, which ought to be constructed of stout oak framing, the head or hinge post of the gate being rounded and nicely fitted to the hollow-quoins above described, while the other heads are carefully chamfered off, so that when the gates are set up in their places, touching the hollow-quoins, and the mitre sills, their chamfered heads shall meet and truly fit ; instead of hinges, either a rounded part of the head of the gate, or a strong gudgeon of iron at the bottom, is let into a hole provided in the stone or timber below, but not fitted thereto so as to bind, or prevent the rounded part of the head from being pressed closely and uniformily into the hollow-quoin by the force of the water ; the top of the gate is kept in its place by a strong strap of iron which goes round it, allowing sufficient space, and is keyed or screwed down to a strong cramp or pin in a large stone, which acts as a coping to the hollow-quoins. The gates are usually planked with deal, sometimes upright, but often in a diagonal direction ; and a square hole is left in the planking of each lower gate, to which a paddle is adapted, with its stem or rod rising up above the top of the gate, by the side of a standard of wood, fixed to the top rail or balance beam of the gate in which is a pinion, working into a rack of cast iron on the paddle-stem,

which is turned by a winch-handle, and the paddle is retained at any height to which it may be drawn, by a ratchet or stop, that can readily be turned up to lock into the teeth of the rack, or turned down to discharge and let down the paddle. The top piece or balance beam is usually a tree of considerable dimensions, having its full size, or butt-end, left unhewed to act as a handle to turn the gate round by, and at the same time to balance it, so that the front of the gate may not drag on the sheeting at bottom; but as it would be very difficult thus to balance large lock-gates, like those at the *London Docks*, a roller of brass or cast iron is fixed under the head of each gate, and a strong circular sill of wood, or rail of cast iron is prepared on the sheeting, for the same to roll freely upon, and cause the gate to open and shut easily: the height of the roller above mentioned is made adjustable by a screw, so that the gate can at all times be kept from dragging on the sheeting: and instead of handles to open such gates, ropes, and chains, and capstans, erected on the banks for the purpose, are used to open and shut them. The upper gates are hung and constructed nearly like the lower ones, except that they have no paddle-holes in them, and are usually boarded no higher than the level of the paddle weirs behind them, in order to assist as weirs in carrying off a superfluity of water; but these are often attended with bad consequences, the fall of the water wearing, and in time damaging the breast of the lock; and in floods the stream or splashing of the water may damage goods in, or even endanger the sinking of heavy laden boats, in the lock; the same may also happen with deeply laden boats when the paddles are drawn in ascending, if the paddle holes do not enter the chamber of the lock at some distance below the surface of the water and in a proper direction: on the *Monmouthshire* canal the paddle-holes are both united, and discharge themselves through the breast of the lock into the chamber; a practice that seems by no means worthy of imitation. The upper paddles, or those behind the upper gates, are drawn by a rack and pinion, by means of a winch-

handle (which each bargeman and lock-keeper carries with him) in the same manner as those in the lower gates, which we have described above. Guard-rails or curving pieces of timber ought to be strongly bolted on to the piles driven for that purpose on the front of the wing-walls just above the surface of the water, to guide the boats into and out of the locks, without striking the walls; which is far preferable to the huge stones let into the wing-walls in some places, called bumping-stones, and calculated rather to break and destroy the boats than protect the walls. It will be necessary also to provide a strong piece of wood formed to the curve of the breast-wall of the lock, before which it should be suspended a few inches above the water when the lock is empty, by means of two or three chains; these are called bumping-pieces, and are intended to receive the stem of the boat, and prevent its striking the wall when the same is not strapped or stopped in proper time; a practice, however, for which the bye-laws or clauses of the act should provide adequate fines or punishments: and strapping posts should be set firmly into the ground in the proper places for the bargemen to wind their rope, or strap as they call it, and by easing it out by degrees, to stop the velocity of the boat before it arrives at the gates or breast of the lock that it is entering. The gates should also be furnished with two or three strong upright planks on the lower side, to receive occasional blows from the noses or stems of the boats, and prevent the planks of the gates being broken or started thereby. There is room for the skill of the engineer to be exercised, in forming the lock-sills and gates to that particular angle which will render them stronger for the same width and depth of lock, than they would be if they met more acutely, or were shorter and met more obtusely. In very large and wide locks, the gates should not be straight or plane, but a little curving to give them greater strength. On narrow canals, it may not be necessary to make double or angle gates, but one gate shutting square across the lock may be strong enough to answer every purpose,

and be opened more readily than two gates on the opposite banks can be ; the upper gates in particular, on account of the comparative shallowness if the water there, may be single, while the lower gates, of the fall is considerable, may be double. In setting out canals, where the fall of ground is very gradual and easy, it may be necessary to avoid long lengths of deep-cutting below, and of embanking above, or making the line very crooked, to make shallow locks, if water is plenty ; and under the same circumstances only, will it be allowable, to make 10, 12, or more feet locks in particular places, however well the ground may suit the same ; many of these double locks were at first erected, as on the old *Birmingham* canal, and the *Calder and Hebble* navigation, where about 1783 single locks were obliged to be substituted, to avoid the waste of water before pointed out.

We have not yet noticed an inconvenience and waste of water which attend the placing of locks nearer to each other than about 100 yards, or having basons between them, equal in area to about that length of the canal, as was done at Salter Hebble in 1783 in the alteration above mentioned ; without which precaution, a boat in descending lets down more water than the pond below will hold, without raising its surface so as to loose a good deal over the lock-weirs, and still worse happens in ascending, for the short pens are so much lowered by filling the lock below, that laden boats are unable to proceed for want of water, until a supply is let down to waste, through the upper locks, to help them forwards. As many locks as can conveniently be brought near to each other, on the principles above, and before explained, should be contrived, if it can be done, to be in sight of each other, end of a length of canal each way ; and the lock-keeper's house should be so placed, that he can when at home at his meals, or otherwise, in bad weather, see boats approaching the locks, in time to meet them before they enter the locks.

Mr. *Robert Fulton* who wrote in 1796 says, that the cost of locks for 25 ton boats, was about £70 per foot

rise, and for 40 ton boats, about £100 per foot rise; this may serve to give some general idea of the cost of locks at that time; but we would observe that the decrease, of the value of money, and the exceptions to all general rules on these subjects are so many, no dependence ought to be placed on such modes of estimating. If sufficient water-way is given in the paddles, and there is assistance enough to draw both the paddles, and open and shut the gates at the same instant, a boat may pass each lock of the usual construction and rise, in three minutes, but in general 5 1-2 minutes will be nearer to the average time lost at each lock, as observed by Mr. *Bevan* on the *Grand Junction* canal. Theorems for the time of filling a lock of given dimensions, and with given paddles and full of water, should be found and compared with many experiments on the locks under the care of our resident engineers It should be considered that a boat going up lets down or consumes twice the weight thereof (boat and cargo included) in water, more than in going down through each lock; for the boat on entering the empty lock, expels as much water into the lower reach as its own draft of water, which is made good out of the upper pound when the boat enters the same; while a descending boat expels its own flotation bulk of water from the full lock into the upper pound, where it is retained on the shutting of the upper gates; the mean of a passage each way will be a lock-full for each boat, unless they go always loaded one way, and empty the other. Mr. *Fulton* says, that the consumption of 25 ton boats through eight feet locks, will in general be about 163 tons of water in ascending, and 103 tons in descending; and Mr. *Chapman* informs us, that boats passing and repassing a summit, laden one way and returning empty, will require nearly 13 times the weight of their lading of water for their lockage, out of the summit pound Seven hundred tons of lading per day are as much as pass or repass upon any one of our canals, according to Mr. *Fulton*.

We cannot with propriety quit the subject of constructing locks, without mentioning *coffer-dams*, which

are a double range of piles drove very close to each other in a circular form round the mouth of any canal or dock, that is to have a lock built, repaired, or altered, connecting with the sea, a river or any existing navigation that cannot be emptied of its water; the interval between the piles being filled with earth, the water in the space between the coffer-dam and the intended works is then pumped out for the works to proceed; the many and fatal accidents to which these are liable, especially when the works are nearly completed, and the earth is excavating from the bottoms to open the passage freely to the lock or works, require all the precautions, skill, and attention of the most able engineers, especially when the rise and fall of the tides or waves of the ocean, present unequal action on the piles or dam.

CHAP. X.

TOWING-PATH, OUGHT TO BE ON THE LOWER SIDE OF THE CANAL. SHOULD NOT BE USED TO DRIVE CATTLE ON. ITS HEIGHT AND BREADTH FENCING A CANAL. SWING-GATES, CYLINDERS OR FRICTION ROLLERS. REPAIRING CANALS. DESTRUCTION OF RATS, MOLES AND HURTFUL PLANTS. METHOD OF REPAIRING A BROKEN BANK. STOPPING LEAKS. CAMP-SHEETING. CLEARING CANAL OF SEDIMENT OR DEPOSIT.

THE *towing-path*, horse-path, or hauling-way, of a canal, should always be on the lower side if practicable, the travel on the same having a tendency to consolidate the new made bank, to prevent the accumulation of weeds and the harbor of vermin, that by lodging in and perforating the bank might endanger the same. The towing-path should change as little as possible from one side of the canal to the other, and when this is una-

voidable, it should be always done at some fixed bridge, to avoid the inconveniencies of fording the canal; the change ought never to be made in deep-cutting, as has been done near Tring on the *Grand Junction*. The towing-path ought never to be interrupted if the same can be avoided; and, besides having ways under all bridges (except those where a change of sides is to be made) we hope to see the example followed which has been set at Atcham on the *Shrewsbury*, and Newbold on the *Oxford* canals, of continuing the towing-path through the tunnels, wherever the same shall appear practicable. On the proposed *Bude and Launceston* canal, it was intended to form a towing-path on both sides; a hint that may prove very useful in some situations of greater traffic, than there ever was likely to be on this canal. Frequently permission is given to persons to use the towing-path as a foot path or bridle road, and we think it would in some instances be proper to obtain the power of levying a small toll on horse passengers; if the company should at any future time see it right by public notice to permit their towing-path to be so used. It seems inapplicable to the purposes of a towing-path, to make public drift-ways of them in any case, on account of the damage which loose cattle would do to the banks and fences, and the impediments which droves of cattle would present to the hauling horses and lines. In forming the towing-path, care must be taken to make the ground sound, and to cover it with a proper thickness of good gravel; and we cannot but recommend the raking or sorting of this as it is laid on, throwing the large or irregular stones forward to be covered with better gravel, so that the surface may be smooth and even, without rough and large stones to throw the horses down, and render the use of the path unpleasant. The height of the towing-path ought not to be less than one foot, or more than two or three feet above the surface of the water, or top-water line, and it should be of sufficient width to allow the towing-horses, when they meet, to pass each other freely and without inconvenience. The *fencing* of the sides of a canal is a business deserving of

more attention than has been usually paid to the same. Quick-set or other line-fences ought by all means to be made, except in the case of a rocky country, where good and durable walls can be built at an easy expense: rail or pale fences are very improper, except in and near towns, on account of their heavy expense in repairs.—Through common fields or very large pastures, (in situations where the canal banks are such, as that cattle would not be likely to injure them,) it is sometimes not necessary to fence off the towing-path therefrom, but at the boundaries or entry to such fields, a gate is placed across the towing-path, to prevent the intermixture or escape of the cattle; and generally these gates are double, falling rather forcibly towards each other, by which construction the cattle are prevented from pushing, or the wind from blowing open the gates, as would otherwise often happen. At the termination of every principal estate or farm that adjoins the towing-path, it is usual to place a swing-gate across the same to prevent cattle getting away, in case they should break, or by accident get into the towing-path. Cylinders (or friction rollers made of hard wood, about an inch and a half or two inches in diameter and of sufficient length,) should be placed against each of these gates for the towing-line to run upon; and side-rails should be placed inclining up to the top of the posts to assist the towing-rope in getting over the same. These cylinders will be found useful, by preserving the towing-rope from being worn out and destroyed, in all situations where the towing rope would otherwise be drawn against the abutments of bridges or other erections on the canal.

On the *repairing of Canals*, we think it necessary to make a few observations; and to begin by recommending the adoption of a system of management, by which the earliest notice of any defect, or want of reparation, will be obtained: that in store-houses, at proper places on the line, a stock of oak, elm, and deal timber should constantly be kept, cut and seasoned, ready for replacing any of the timbers or planks in the locks or o-

ther works, with the least possible delay to the trade, a circumstance which, if not attended to, may prove of incalculable injury to the credit and success of the concern. Sound and good bricks, and stones, ready for replacing any which are liable, or observed to be likely to want repair should also be in readiness, and good cement should be always kept on hand, on some part of the line, from whence the quantity wanted may be speedily transported to any part where a reparation of the walls, bridges, culverts, &c. may require the same: however, before emptying any part of the canal, or interrupting the trade for any reparation, a strict search should be made throughout every part in that level, or on the adjoining ones, to discover all the defects therein, that arrangements may be made beforehand for repairing the whole at once, or with as little delay as possible, while the trade is interrupted on the line. In every storehouse a considerable number of the *pile-planks* before described should be kept piled up in readiness, for making temporary stanks or dams, in order to empty any particular part of a level, which may have a culvert, trunk, sluice, or stop-gate, lock-sill, or other thing which is damaged, out of order, or decayed. It is surprising, to those who have not seen such works performed before, with what facility the workmen who are used to this business will drive two rows of pile-planks so regular and close to each other, that by the help of the tongues or slips in their grooves, and often without, a tight stank is made without any earth or other loose matters to stop the water; and between two of these stanks, if such are necessary, they will empty the water by chain-pumps, or water screws, to get at any culvert, or other matter, to be repaired or altered; there have been instances of these operations being performed, and of the part being filled with water, and the pile planks drawn up again for the trade to pass, in the space of eight or nine hours. Should any part of the canal appear to want new lining or puddling, owing to a neglect at the time of making the canal, or to any subsequent accident, care should be taken to choose the time for such works, when the

trade can best bear an interruption; and as, on the average of seasons, the trade is two or three weeks interrupted by ice, during the months of January and February, it may not be amiss to embrace that period, on some occasions, although it will take longer to perform the work, and some additional expense may be incurred by covering up the work with earth before it is left at night to prevent its freezing, and in removing all such puddle, &c. again in the morning, or at beginning work, which shall be found frozen. Previous and explicit notices should be given of all intended interruptions to the trade, as long beforehand as is necessary, to enable the traders to supply stocks of articles at the places of consumption on the line, and to avoid having their boats locked in, and perhaps lying idle, when they might have been employed if they had been on a different part of the canal.

It is an essential point of good management to have experienced mole and rat-catchers employed from time to time upon the line of a canal, to extirpate those hurtful vermin; and in every instance of discovering one, to trace out all his burrows and holes, and have them carefully stopped up and filled in every part, as well for preventing the harboring of other animals of the same sort, as for preventing the water from making its way into and through them. On a canal in Surry, we are told by Mr. *Robert Marshall*, in his *examination of a canal and rail-way, &c.* that a *mole* or *rat hole* only, occasioned, after the hard frost of 1795, the rupture of the canal, in a high embankment, by which more than 100 yards in length of a lofty bank was precipitated into the meadows and river below, and that a boat which before lay enveloped in the ice on the canal, was hurried down through this gulph into the river! It is impossible to take too much care against such fatal disasters as these, and the duty of the mole and rat-catchers ought not to be limited to the company's ground, but in all fields, banks, ponds, or brooks within 100 yards or more of the canal, on each side, they ought to be equally attentive to the destruction of such vermin, and the demolishing

of their secret retreats. The same men might very properly be employed in pulling up and extirpating all large and spreading weeds from every part of the banks of the canal, and in mowing down the herbage occasionally; these circumstances being not less essential for the neatness and beauty of the canal, than to prevent the first harbor of vermin of different kinds. The banks of the canal will be very apt to continual wear at the surface of the water, and for some height above and below that level, if a proper kind of herbage is not encouraged upon the slope of the bank; considerable care should be taken to suffer no plants to take root on or near a canal bank, or spread its seed, (if possible to prevent it where water is taken into the canal by a feeder), which will grow in deep water, or whose roots are large, hollow, and strike deep into the ground, lest the former of these should choke the canal in time by weed beds, and the latter render it leaky by the formation of numerous open tubes through the lining into porous stuff. None but those who have seen many drains or new ditches opened in wet and boggy ground, can be aware of the depth, size, and number of hollow roots, which some of the aquatic plants, as the *equisetum palustre*, or marsh horse-tail, the *iris pseudacorus*, or yellow flag, and several others, send forth into the ground.

Puddle-ditches in the banks that are raised or made up, are a great security against the bank being washed down, in case of the water, risen by any sudden thunder shower, or other inordinate rain, breaking over the top of it; as soon as the puddle is reached, the effect of the stream to tear and lower the bank will often be stopped; for good puddle, when properly set and hardened in the centre of a bank, is so compact as not to be liable to be abraded or suddenly worn by a current of water.—In case of the breaking or slipping of a bank, so that a considerable and wide breach is formed, and still increasing, it is a good practice to drive in two rows of common fold hurdles at a foot or less apart, lashing the same well together by cords, and securing them by strong stakes drove down behind them, and if the stream of

water be deep through the breach, it will be necessary to drive other long stakes obliquely into the ground, and securing their tops to the hurdles and upright stakes by laps of cord, that these last may act as struts or props to prevent the whole from being borne away: into the cavity between the hurdles, straw or stubble should then be put and trod down, beginning at each end and working towards the middle, in order to prevent the current being turned, with fresh impetuosity, against the sides of the breach; such a dam as this will prevent the loss of any considerable further quantity of water, and will render the water stagnant, so that a row or more of pile-planks can be drove to cut off the connection with the breach, which can then be emptied of water, the hurdles and straw removed, and the reparation begun, with proper puddle-ditches for its security, as before described. At the famous Dagenham breach of the embankment of the *Thames*, dove-tail or plank-piles were used, we are told.

Leaks in a canal may sometimes be stopped without emptying the water, if the depth will permit it by preparing good puddle in a flat bottomed dirt-boat or flat, and dropping the same in spade-fulls equally over the surface, and when a certain length is done, raking the same about with a rake with short teeth, to join the pieces together, and level the bottom. The difference in specific gravity in different loams and earths, is so considerable as to make some of them much more proper for the lining and facing a canal than others; the heaviest that can be found should be used when leaks are to be stopped, and the water remain in the canal as above. We have passed along the branch of a canal on a chalk soil, where the lining of the bottom was so light, that the motion of the barge stirred enough of it up into the water, which was before nearly clear, to make it almost as white as milk behind us; this light stuff has since been taken out and a substantial lining and facing of proper stuff, brought in barges for the purpose, and laid on the bank before the water was let out, has been applied, by an able engineer, who succeeded those of too

different a description who constructed this very leaky branch.

It will be necessary to defend many places of the banks of a canal that are obliged to be unusually steep, as in the approach to a bridge or lock, a wharf, &c. with a facing of planks, called *camp-sheeting*; this consists of strong piles driven into the bottom of the canal, with the proper slope or inclination, with horizontal pieces, or land ties to their tops, on which piles, sound and durable planks are spiked.

In some places, owing to the accidental or unavoidable admission of very thick water into a canal, or in more cases by the ordinary deposit in length of time, the canal will become choked with mud. In these cases a machine with buckets, like a chain-pump, to scrape the bottom of the canal, and afterwards discharge the load of mud into a barge, might be used, such a machine, worked by horses, being now in use in the *West India Docks*.

CHAP. XI.

DRAINING, ITS VARIOUS OPERATIONS. CONSTRUCTION OF BOATS; IF TO MOVE FAST, SHOULD NOT BE ONE THIRD AS WIDE AS THE CANAL. SHAPE OF THE HEAD. FLAT-HEADED AND WITH RECTANGULAR ENDS OUGHT NOT TO BE TOWED FAST. MULES USED ON BRIDGEWATER'S CANAL. RATE OF TOWING PER HOUR. REMARK AND NOTE RESPECTING THE WEIGHT WHICH CAN BE TOWED ON A CANAL.

DRAINING is a business of which a canal company will have a good deal to perform in most cases. Soon after a canal is filled with water, and often sooner on the upper side, owing to the course of the land-springs, and those of a more permanent character

being intercepted by the puddle-ditches, wet places will appear on the land, which, would, if neglected, become unfit for cultivation: these are often of considerable extent below the canal; and the committee of the canal company must not be surprised at hearing the farmers attribute many wet places in such situations, to the soakage of their canal, that really are not affected thereby. It would be of use, and the source of much satisfaction, if the resident engineer were to note down in his book all the wet and springy places that appeared on the sloping land, below the level of the canal for a considerable distance, and the condition or run of water from each before the canal was made; because the appearance of new queaches, as the farmers in many places call them, or the increase or enlargement of others, is often the first and only indication of an increasing and hurtful leak from the canal. The committee should not be nice in drawing the line, as to the extent of draining which they order to be done; but it would, on the contrary, be highly to the credit of their concern, and the interest of future canal schemes, to bear the whole or a portion of the expense of effectually draining all the land, whose wetness could, even in mistaken prejudice, be ascribed to their canal. The execution of these operations ought not to be confined to the quackery of boring a hole here and there in a trench, without any theory or meaning; but the resident engineer or some professional man employed expressly for the purpose, should, by a judicious application of his experience and knowledge of the *strata* in every place, apply that particular method of draining, as to the situation and depth of the drains, &c. which every spot may require. And these operations are more various and important than any person, who has not made the subject his particular study, can possibly be aware of. There is a danger attending drains made near a canal, from rats or moles working their way unobserved beneath the surface, between the drain and the canal; for detecting which, or other leaks, it will be proper for the engineer to enter in his book a minute description of the situation of the

mouth or vent of every drain, choosing situations for the same, when they are made, in ditches, where they can be readily got at, and not be liable to be damaged by time, or the treading of cattle. The length and direction of every branch of under-drain which vents at that mouth, should be noted down, and the quantity of water which the drain discharges should also be carefully estimated, at some short distance of time after the same is finished; and a regular and periodical inspection of these drain-mouths by the engineer with his book in his hand should be made, by which any secret leak could hardly fail of being detected. It is almost unnecessary to point out the importance of an attention to these circumstances, in situations where water is very scarce.

The *construction of Boats* for canals requires some notice in this place. Mr. *Chapman*, who has given some excellent directions respecting the form of boats least liable to overset or be injured by heeling, has very properly observed (*Observations* p. 102.), that the area of a cross section, of a boat to be used on a canal, ought not to approach so near to the area of a cross section of the water in the canal as 1 to 3, or considerable inconvenience will arise, both from the increased resistance of the boat, and the damage to the banks, from the counter current to fill up the space the boat leaves in her rear. This circumstance requires particular attention, particularly in boats that are to move quick, like the passage boats from Manchester and Paddington, on the *Bridewater's* and the *Grand Junction* canals: in the former of these, we observed a constant elevation of the water before the passage-boat, as it moved along, of at least 9 inches, and perhaps more than a foot at times; and the rapidity with which the water run backwards, between the boat and the sides of the canal, appeared to have a most destructive effect upon the latter, particularly on the towing-path side; and often this was laid quite under water, for considerable distances together, by the surge or wave opposite to the head of the boat as it passed along: while the labor of towing was most materially increased. We regret that we had not the

means of ascertaining how much the head of the boat was elevated upon this artificial wave in the general, and up which inclination the towing-mules were constantly drawing it. Some attention ought to be paid to the form of the head and fore part of the boat, (if it is designed for quick passage,) with a view to its letting the water pass freely off by its side: flat-headed boats, and those whose ends are rectangular in particular, ought not to be towed fast, or great loss of labor and damage to the banks will be the consequence, unless the canal is very wide and deep.

Horses are now, in general, used for towing boats on our canals, except the late Duke of *Bridgewater's*, who reared a large and fine herd of mules, that were found to answer so well, that none others are used to this day, we believe, on that canal. Except with passage-boats, and flies or packet-boats, for the expeditious conveyance of packages and parcels, the usual rate of towing upon our canals is about two and a half miles per hour, including the time lost in passing the locks, which, if of eight feet lift or rise, will require about five and a half minutes each. It is certain that there is hardly any limit to the load, which one horse can move, in a number of barges attached together, when going with a proportionably slow pace; and this has occasioned some canal advocates to assert that one horse will, on a canal, draw as much as sixty on the road.*

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* Mr. Gallatin, (see his *Report*, p. 49, in the latter part of this volume,) speaking of the transportation on the *Middlesex* canal, states, that "eight hundred tons of timber, has been drawn by two oxen, part of the way, at the rate of one mile in an hour." The *Middlesex* canal is about 27 miles long; therefore, at the rate above mentioned, excluding the time of passing the locks, the two oxen, by laboring 9 hours per day, would transport 800 tons of timber 27 miles, the whole length of the canal, in 3 days.

How long a time would it require, for two oxen to transport, by land, an equal weight? Making a reasonable allowance for bad weather, and bad roads at the breaking up of winter, &c and excluding 52 sabbaths, it is not believed they would be able to labor, on an average, more than 200 days in

CHAP. XII.

GENERAL MANAGEMENT OF A CANAL. APPOINTMENT OF SUBORDINATE OFFICERS. GAUGES. CANAL REGULATIONS TO BE PRINTED AND PUT UP. OFFENCES, HOW NOTICED. TONNAGE TABLES. WEIGHING-HOUSE. GAUGING AND MARKING THE TONNAGE OF BOATS.—TONNAGE REGULATIONS. RAISING SUNK BOATS.—REGULATIONS FOR THE MANAGEMENT OF BOATS, AND FOR PASSING THE LOCKS. RATES OF TOLL.

ON the general management and office department, of a canal concern, it is unnecessary to make many observations. The committee with which the conduct of it is entrusted will, without doubt, direct their attention to those various circumstances on which its prosperity depends. Accordingly, they will appoint proper officers in the several subordinate departments, and give them such instructions for the regular discharge of their duty as occasion may require. It may not, however, be improper to suggest, that the canal committees should direct their resident engineer to establish proper rain and evaporation gauges at several lock-houses upon the line, to be kept by the lock-keepers, and registered daily or weekly with great care: these observations, preserved in the company's books, or, what would be better, published in some of the magazines, would prove of great advantage to science, and to canal undertakings in general. In canals of considerable length, particularly if some parts of them are indifferently and variably supplied with water, or leaky, it

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a year, and that they could not transport a ton 27 miles, and return again for another load, in less than two days. This supposition is, probably, much beyond what they could actually accomplish; and yet, at this rate, only 100 tons would be transported yearly, and it would, consequently, require the labor of two oxen *eight years*, or 2920 days, to perform the required work.

will be right to fix gauges or graduated rods on each upper lock-gate, that would shew at all times how many inches depth of water there is at the time, in the shallowest part of that pound; and to cause the lock-keepers to mention the same at the foot of the printed permits or pass-tickets, that the toll-clerks should give to every bargeman who passes, containing the number and description of each barge, and the description and weight of its loading; these, transmitted regularly to the toll collector, would enable him, or some other person, to keep for the information of the committee, a register of the daily state of each long or leaky pond of water; at the same time that the lock-keepers, toll-clerks, &c. at each extremity, and on different points of the canal, would always be acquainted with the state of the water, and the loading which a barge could pass with at every particular place; and could inform bargemen; for want of which knowledge great delay and expense are often incurred, in dry seasons, by setting off with more lading than can be carried through, for want of a sufficient depth of water, and part of the same is obliged to be left on the road, or taken into other boats. All the regulations contained in the act, for working of the canal, and such by-laws as the committee may see it necessary to make, for regulating the conduct of the bargemen and others on the canal, should be printed, and stuck up at every wharf on the canal, and in every toll-clerk and lock-keeper's house; and all the company's agents and servants should be strictly enjoined to notice every breach of laws and regulations, not by altercation with the offenders, but by immediately noting down in writing the exact and true particulars of the time, place, and name of the offenders and bye-standers or witnesses, &c. transmitting the same immediately to the committee, and preserving a copy thereof themselves: and, though we are far from recommending severity in punishing on these occasions, yet a system of this sort, by shewing the offenders that the committee would always be prepared to proceed against them, would, in most instances, especially if the parties were

written to, to threaten them, go a great way to prevent the same parties or others from offending again.

Tonnage Tables, fully and explicitly stating the toll or tonnage payable to the company, on goods or articles of every different kind, or on different parts of the line, if, as often happens, these vary, should be printed and stuck up on all the wharves and toll-houses, for preventing all doubts or altercations between the company's servants and the traders. At some convenient place on the line of the canal, a *weighing-house* should be prepared, consisting of a dock under cover, large and deep enough to contain the largest vessels which are to navigate the canal; this dock should be furnished with a draw-gate to let down, or doors to shut, when an empty barge has entered, in order to render the water quite still within the dock.

Cast iron or leaden weights of 2 *cwt.* each should be provided, and a crane to hoist the weights readily in or out of the barge, and place them in any part of the same, so as always to load her evenly. To this weighing-house, the act or by-laws should require every boat to be sent, having the name thereof, and the owner's name and residence previously painted on the stem of it, before it is allowed to trade on the canal: the empty boat being arrived in the dock, the gauging master fixes four small plates of iron, each containing the *number* that this barge is in future to be distinguished by, two on one side and two on the other, against the gunwale, near the head and stern. These plates are all fixed at the same distance from the surface of the water, when the barge is empty; this distance, in inches and tenths, is entered into the gauging-master's book, under the number of the barge, name, owner's name and residence, date, and other particulars; two tons of weights are then hoisted into the barge, and regulated until the distance from all the four plates to the water's surface is the same, which distance in inches and tenths is also entered in the book against two tons; two tons more of weights are then hoisted in and adjusted, and the height of the number-plates above the water is taken and en-

:ered against four tons as before; these operations being repeated until the utmost lading of the barge is on board, when the weights are taken out again, and the barge removed from the dock. For measuring the height of the plates at the Paddington weighing-house, a tin tube is used, that is furnished with a float moving freely in it, to mark the surface of the water, which carries a light stick graduated to inches and tenths, to shew the height of the number-plate against which it is applied. At every toll house on the *Grand Junction* canal, similar floating-rods are kept, and to every laden barge which passes, this gauge is applied against the number-plate, at each end, and to those on the other side, if the barge appears to heel at all to either side. If the dry inches and tenths shewn by the gauge, between the number-plate and the water's surface, are different, they are added together, and divided by the number of them for the mean height. It is the business of the gauging-master to calculate, from the particulars entered in his book, of each barge as above, the weight to the nearest of 1-4 of a ton, which answers to every inch and tenth of an inch, of the dry inches shewn as above by the gauge; the number of the barges are applied in a regular series in the order in which they come to be gauged; and a book, containing a table for the tonnage on board, answering to every dry inch and tenth, as above, is calculated, and a copy of each is in the possession of each toll-clerk, by a reference to which, he sees, and enters in his toll-book, and in the pass-ticket or permit, the number of tons and quarters for which tonnage is to be paid to the company. On a great number of canals the practice is different; the gauging-master prepares four slips of copper or lead, about three-fourths of an inch broad, and one eighth thick, and stamps thereon at every division answering to two tons, agreeable to the observations entered in his book, and between these, strokes are drawn to mark the intermediate tons and quarters of a ton. These plates he sees carefully nailed on to the sides of the barge, under the number-plate; by help of which, the toll-clerk,

and the barge-man also, can at any time see the tonnage on board, by the place on the plates cut by the waters's surface.

Most acts contain a provision respecting barges occasionally navigating a canal or any others where reason appears to the toll-clerk to suspect a deception or fraud, for requiring the bargeman to give an accurate account of his lading on board; which if unsatisfactory, the toll clerk may take such barge to the nearest wharf where accurate scales, steel-yards, or engines for weighing goods are kept, and there have the cargo unloaded and weighed; which expense, as well as penalty the bargeman is made to pay, if he had refused or neglected to give an account of his lading, or if his account so given shall prove below the real weight of the goods. New barges are usually indulged, in two or three voyages, before they are gauged, in order the better to suit the bargeman's and gauging-master's convenience for doing it, during which they are subject to have their goods weighed, as they also are, whenever they have different goods on board, liable to different rates of tonnage, and do not give a satisfactory account of the weight of each.

A clause will be necessary, to punish persons who are found throwing ballast or any kind of soil overboard or into the canal, by which it might be choaked up: it will also be requisite, strictly to prohibit the throwing of loose stuff, as chalk, gravel, sand, &c. by means of shovels from heaps or barrows on the bank, into the barge, unless a broad and close stage of boards was first laid to catch the stuff, which will unavoidably scatter, and to prevent its falling into the canal.

Necessary tackle should be kept in readiness, for weighing up such barges as are sunk, without delay, on account of the total interruption that such will often occasion to the navigation. Where a sunk barge lies so that another barge can be floated on each side of it, the following method may be adopted: chains should be looped round the sunk barge and hooked, having four ends of sufficient length proceeding from near the four corners of the barge, two empty barges should be brought,

one to each side of the sunk one, and strong beams of timber be laid across each of these barges, and the space between them; water should then be admitted into each of the barges by their plugs, to sink them almost to the water's surface, the plugs should then be put in, and the four chains be fastened tight to the cross beams, when a pump should be used in each of the barges to throw out the water, and as this is accomplished if the chains are properly fixed the barge will be buoyed up, often to the surface of the water, so that she may be freed by pumping her; if not, she must be shoved along, suspended between the light barges, to some strong crane, where she can be further assisted, or in some dock or shallow place, where she can be relieved by a repetition of the same process.

Several further *regulations for working of canals* remain yet to be mentioned. They are such as relate to the penalties that should be provided in the act or by-laws, for preventing bargemen from taking in above a certain weight, adapted to the size of their boat and the depth of the canal; and also for preventing such boats from damaging the lock-sills or bottom of the canal, or sticking fast to the interruption of other boats. The nature of the lading and the manner of disposing it in the boat, so that the sides of the bridges, &c may not be injured should be duly attended to. Penalties should be provided to punish those bargemen who suffer their boats to strike against any of the locks or bridges, or those who suffer their barge to lie either for unloading or any other purpose so as to obstruct the passage of other boats. In some acts this penalty is fixed, by the hours that such interruption continues, and at an increasing rate. Boats left at wharves or other places on or by the line of the canal, should be moored at both their ends. Bargemen should be prohibited from fishing or having tackle for such purpose on board. It should be provided, and made known by the by-laws, that barges or vessels going one particular way on the line, and on each of the branches should give way for those they meet or have occasion to pass; and on narrow canals or

branches, it should be provided, that when two boats that are meeting each other first come in sight, or one of them hails the other, that which is nearest to a passing place, shall stop at or go back to the same to let the other pass. Common trading barges and vessels, and all others, should be prohibited from passing any locks or moving along the canal except in the day time, and for this purpose it is usual to divide the months of the year into three or four portions, and to specify the hour both morning and evening in each, between which the canal is to be open. Light boats, for the conveyance of market goods, parcels, &c. are allowed on some canals, as the *Grand Junction*, to pass on during the night, their owner paying a specified sum for a licence for such privilege, engaging to employ the most careful and experienced boatmen, and to make good all damage which such boats may do to the works of the canal, or to the barges or property of other traders. Mr. *Thomas Pickford* the great waggon proprietor, has substituted boats in place of many of his waggons, and which travel night and day, and arrive in London with as much punctuality from the midland and some of the most distant parts of the kingdom, as the waggons do.

A few of our tunnels are constructed wide enough for two wide barges to pass each other therein ; it may become necessary, in such cases, where the tunnels are long, to establish an overseer at each end of the tunnel, where a bason of sufficient dimensions for several boats to lie and pass should be provided, to suffer no barges to enter at either end for an hour, or other period, or until the last boat from the other end is come out, to prevent wide ones meeting others in the tunnel. If the number of wide boats be very small in proportion to the narrow ones, the periods for the entry of narrow boats may be oftenest repeated, and wide boats might, in extreme cases be only suffered to pass the tunnel between the two basons after dark in the evening when the other boats are lying still on the canal.

Gentlemen's pleasure boats, and narrow short husbandry boats, for the use of the occupiers of the lands on

each pound, are often allowed at very easy rates, if not quite free of tolls; and sometimes such as well as any other boats laden with manures and road materials, are allowed to pass the locks on the same conditions, at such times only as the water runs over the lock-weirs, or is within a very small quantity, as half an inch of that height.

The regulations for vessels *passing the locks*, are usually very explicit in canal acts, that boatmen may not suffer the water to remain in the locks longer than is necessary for their boats to pass; that every boatman in going down a canal shall, previous to his bringing his boat into any lock, shut the lower gates of such lock and the cloughs thereto belonging, before he shall draw the cloughs of the upper gates; and, after he shall have brought such boat through the lock, he shall then shut the upper gates, before he shall draw the cloughs of the lower gates, and in going up the canal, such boatmen, as soon as he shall have passed his boat through the lock, shall shut the upper gates of the same, before he shall draw the cloughs of the lower gates, unless there shall then be a boat coming down the canal, in sight of the said boatman, in which the lower gates of the lock shall be left shut, and the upper gates shall be left open; and in all dry seasons, or where there shall be a scarcity of water in the canal, the boat so going up (if within sight of a boat so coming down) and at a distance not exceeding two hundred yards below a lock, shall pass through such lock before the boat coming down, and then such other boat shall come down into the lock; and if there shall be more boats than one, below and above any lock at the same time, in any such dry season, within the distance aforesaid (which distance shall be distinguished by a post set up for that purpose,) such boats shall go up and come down at such lock *by turns*, until all the boats have passed, by which means one lock full of water may serve two boats. A penalty should be provided against any bargeman or other person, who draws the cloughs, except while barges are passing, as above, or for leaving any clough open; as also against any lock-keeper or o-

ther servant of the company who gives undue preference to any boatman in passing the locks, or in unloading his barge at the public wharves. Posts should also be provided by the side of the locks, for strapping or stopping the velocity of boats before they enter the locks, and penalties ought to be provided against the winding of their rope or strap round any part of the gates or lock, in order to stop a barge, except the strapping posts before mentioned; after all, the engineer should be careful to form the heads of the gates, and all other projecting points about his locks, of such a sloping or wedge-like form, that the rope would have no hold of them, but slip off. A clause should always be inserted in the act, for making master boatmen answerable for all damage done by their servants, giving them, however the right of recovering from their servants in all cases of wilful damage or neglect. On some canals, it is usual, for the masters to hire their men by the ton of goods which they navigate certain distances, instead of paying them by the day for their time.

For some time past, the rate of freight on some canals, over and above the company's tonnage, has been two pence per ton per mile, for unperishable goods, three pence per ton per mile, for perishable goods, and four pence half penny for bulk goods. In times of distressing scarcity, like those of 1795 and 1800, the committees of several canals, have permitted the passage of imported grain, going towards the interior of the country, toll free, with the laudable intention of lowering its price to the community.

CHAP. XIII.

IMPROVEMENT OF RIVER NAVIGATIONS. DIFFICULTIES. VARIABLE STATE OF THE WATER. DIMINUTION OF STREAMS ON CLEARING AND IMPROVING THE COUNTRY ABOUT THEIR SOURCES. CAUSE OF SUCH DIMINUTION. COUNTERACTING CAUSE. RUNNING CANALS. SIDE-CUTS. COUNTER-DRAINS. SLUICES. OPENING WEIRS. ONE ON THE THAMES. JETTIES, WIER-HEDGES. IMPROVEMENTS SUGGESTED BY MR. TELFORD EXPENSES AND INCONVENIENCIES THEREOF. CLEARING OUT THE BOTTOM OF RIVERS. MR. BRINDLEY'S OPINION OF RIVERS.

THE *principles of constructing or improving river navigations* requires some notice. Mr. *Thomas Telford* has given an account of the navigation of the river Severn, which is printed in *J. Plymley's Agricultural Report of Shropshire*, pages 284 and 317, from which we shall collect some particulars, and remark thereon, with a view of shewing by an example what are the nature and extent of the difficulties which navigation has to contend with, upon natural rivers. Mr. *William Reynolds*, the founder of *Coal-port*, caused an account to be daily registered, of the depth of the stream, in the bed of the *Severn* river at that place, between the 7th of October 1789, and the 23d of December 1800, of which Mr. *Telford* has given us the particulars, except on 12 occasions when the river had overflown its bounds and covered the usual marks, on Sundays during some part of the time, the intervals of frost in which the river was frozen over, and for three short intervals, when unfortunately the experiment was by some accident suspended. These valuable materials we have examined, and shall present the reader with some results therefrom, that will be of use in judging of the interruptions from floods and drought, to which river navigations are liable.

From the observations made as above, it appears, that the *Severn* river at Coal-port is subject to about one overflowing of its banks annually, besides about 20 lesser floods, varying (in eleven years) from 16 to 3 feet in height, the mean height of which is about 6 feet 7 inches. It also appears that the greatest floods and those occurring the oftenest, are in December and January; that the fewest floods happen in May and June, and are the least in height in June and July. With respect to drought or diminution of water, it appears, that the Severn at this place is subject to between fifteen and sixteen low states of the water annually, and each of them will be found of much longer continuance than the floods are; the lowest having 9 *inches only* in depth of water, the greatest that we have here taken out being 1 foot 10 inches, and the mean of all such we find to be 1 foot 4 3-4 inches. It also appears, that it is not oftener than once in two or three years on the average, that a low state of the water (1 foot 8 inches) occurs in any of the four winter months, November, December, January and February; that June and July are subject to the lowest waters, and July and August to the most frequent rises of the water; the reason of this last circumstance appears to be, that in this low state of the water, and when the breadth of the river is the least, the effect of almost every partial thunder, or other heavy shower, on any of the branches of this river, is visible in the same at Coal-port, which waters could not have been noticed, when the stream was so many times larger as it generally is. Only twenty-six instances occur in all the eleven years, of the water remaining for more than four days together at any other height than 1 foot 4 inches, several of these being very near that height; and, indeed, instances of a stable height are so rare, that often for months together no two following days are to be found alike.

Mr. *Thomas Telford* remarks, that the year 1796 afforded so striking an instance of the fluctuating nature of this river, that during the whole of that year, there were not two months in which barges could be navigat-

ed, even down the river with a freight which was equal to defray the expenses of working them; an interruption to trade that was severely felt by the great coal-masters and manufacturers of iron in those parts in particular. The same intelligent engineer observes, when speaking of the *Severn*, "the inconveniences arising from the irregularities of the water have always existed in some degree, but they have been greatly increased by the embankments which have lately been raised to protect the low lands in Montgomeryshire, and in the upper parts of the county of Salop. Formerly, when the river had arrived at a moderate height it overflowed these lands to a great extent, which thereby operated as a side reservoir, and took off the top waters of the high floods; and these waters returning to the bed of the river by slow degrees proved a supply for the navigation, for a long time after the flood began to subside, but being now confined to a narrow channel, they rise suddenly to a great height, and flow off with more rapidity than formerly; whereby the navigation is at one period impeded by uncontrollable floods, and at another left destitute of a sufficient supply for its ordinary purposes." Besides the embanking of low lands by the sides of considerable rivers noticed above, another cause has been observed by us, for the change for the worse, which is well known to have happened to many of our navigable rivers, within the last 50 years; in which period, a great portion of the common-field parishes in England have been enclosed, and in the greater number of instances, new and straight brooks and water-courses have been cut therein, instead of the exceedingly crooked and serpentine courses which most of them formerly had; these have had the effect of carrying off rain waters much more freely and quickly than formerly, and have occasioned floods much more sudden and high than were probably ever before experienced. At Bedford on the *Ouse*, we have read of two or three immense floods, within a few years past; such as would have effectually prevented the erection and

growth of the south part of the town on its present site, if such floods had ever before prevailed.

The same causes which have occasioned this increase in the rapidity and height of the floods, have, as observed by Mr. *Telford*, caused the quantity of water in general, to be less in our rivers ; a circumstance which receives strong confirmation from an able pamphlet, said to be written by the late Mr. *Wedgewood*, in 1765, entitled " A View of the Advantages of Inland Navigation," wherein it is mentioned, speaking of the *Severn* river near to Coal-port, " that the lowest water that ever happens, in the driest summer, is *never less than* 18 *inches*, which is sufficient to carry vessels of 16 or 17 tons burthen at any time." We have seen above, that this river, since 1789, often runs with a stream no more than 16 inches deep for considerable periods together, and is frequently so low as not to have a foot depth of water in it, while instances of such extreme drought have been recorded, that the depth was reduced to 9 inches, or half what was formerly said to be its lowest state. The progress of agriculture improvements in the last age would have had a still more sensible effect, in producing a low state of the water in our rivers, after the sudden floods are run off, but for another, and contrary effect from the above, by which they are accompanied ; we allude to the more general drainage and cultivation of the surface of the ground, by which it is enabled to absorb and take in so much greater a portion of every shower of rain than formerly, most of which water afterwards finds its way through land, or permanent springs, to the brooks and rivers, and prevents that very diminished state of them, which every dry season must now otherwise occasion. We may consider that all land, whose surface is wet, and in want of draining, is in that state as incapable of absorbing or retaining the rain waters, as the tiles of the roofs of houses, or the paved streets in a town are ; and, that when that most essential of agricultural improvements, underdraining, has been applied, and the surface rendered fit for cultivation, the whole of a large portion of the

showers of rain, and a considerable portion of all of them, are absorbed and retained in the land, to be afterwards slowly given out, by the under-drains or springs, for equalizing the rivers.

In projected improvements upon any of our old river navigations, or in extending the navigation thereon above the tide-way, it is of importance to examine the state of the whole country, to which the river in question acts as a drain, to observe accurately whether cultivation, or the breaking up of lands, and the practice of draining have been going on, or are likely to be so in any considerable degree, within a reasonable period; as also to observe particularly the state and extent of the valleys and meadows, over which the waters are or have been spread in ordinary floods, and the probability of such being further prevented by straightening or enlarging the beds of the brooks and rivers, or embanking the courses of the streams; these, with the most correct information that can be obtained from different millers and others, who live on the banks of the river, or from scientific individuals, who have caused accounts to be kept of the height of the water, will be necessary data for determining the magnitude and nature of the works which will be necessary on the proposed navigation.

Mr. *William Chapman* seems to incline to the opinion, that locks may not always be eligible on river navigations, and says in his *Observations* p. 87, that "during the flooded state of rivers, all small falls are equalized, as they necessarily rise higher below than above a rapid; therefore I am far from saying that running canals with a small fall are not, in many instances, eligible on the shores of great rivers; and that well devised stops, easily opened and closed, (not such as lift up like those described in China, nor open against the streams as gates,) are not sometimes preferable to incurring the charge of locks. In other nearly similar instances where locks are eligible, their piers and gates alone, will be sufficient without any other floor or side walls, than a concave and battered pavement, continued

through the bottom and up the sides of the space between the piers The eligibility, and the particular construction of these works, will much depend on the nature and extent of the beds of the rivers, the difference between their low and flooded states, the height and also the permanency of their shores and the quantity of floating ice.

The greater number of rivers through which new navigations are now required to pass, will be found occupied by mills, at shorter or longer distances from each other, according to the fall of the water in most instances; at the tail of most of such mills, will be found a large and deep pool, which the fall of water from the mill-courses and flood-gates has torn and excavated, and a short distance below this pool a shoal or bed of gravel, or other matters, will in general be found, that would prove so expensive to remove, and would in general be so subject to accumulate again by a further excavation of the pool from the increased fall of water into it, that it will in general be the cheapest and most effectual way to begin a new cut for the navigation below this shoal, and continue the same up by the side of the pool to the bank of the mill, wherein a pound-lock must be constructed, either of timber or masonry for gaining the ascent to the mill-dam or upper pound. In rapid rivers subject to great floods, the utmost care and attention of the engineer to the construction of such works will be necessary, to prevent their being demolished by the first flood perhaps after their erection. Where mills do not intervene, and rapid and of course shallow places occur in the bed of the river which is to be made navigable, a side-cut must be begun from above such shallow, and if practicable, at the beginning of a considerable bend of the river which the side-cut may cut off and shorten; in continuing this side cut downwards towards the place where the lock is to be placed, and the junction below the same is to be formed with the river below the shallow, care must be taken to conduct the side-cut, which is to be upon a level as far as the lock, as soon as possible across the flat mea-

dows to the borders of the high ground, along which it should skirt, to the place of the lock, if this is practicable on account of the width of the meadows; otherwise a counter-drain or parallel cut must be taken up from below the lock, as far as is necessary, on the land side of the side-cut, to drain off the water, and prevent a swamp or pond being formed above the lock and between the side-cut and the high ground, as is almost invariably done by the ancient mill-dams on most rivers and streams: it is, however, with the utmost care and precautions that the counter-drain should be adopted, otherwise, in time of floods, when the meadows are overflowed, such a current would rush into and down the declivity of the counter-drain as to endanger the tearing thereof, and of the bottom and sides of the cut or bed of the river, into which it vented below the lock. We have seen large and expensive sluices erected upon and near to the vent of counter-drains circumstanced as above, of greater height than the top of the floods, which were found necessary to be built, and kept shut on the approach of a flood to prevent the action of the counter-drain, until the flood had subsided so far as not to overflow the meadows adjoining the counter-drain. Across the bed of the river at the most convenient place below and near the upper end of the side-cut, an opening-weir must be constructed, by which the water in the river can always be kept at a proper height for covering the shallows and bed of the river to a proper depth for the navigation; several of these opening-weirs have within a few years been constructed on the *Thames*, one of which near Windsor has been described and drawn by Mr. *Zach Allnutt* in his *Considerations on the best mode of improving the River Thames*, 1805 p 22 It consists of several strong piles or posts driven firmly into the bed of the river at 20 to 25 feet apart, in a straight line across the river: the intervals between these piles are driven and nicely filled up with pug-piles, or dovetail piles, such as we have described when treating of locks: these last are afterwards sawed off straight and even with the bottom of the river, and have a strong and

sound sill nicely fitted and spiked on to them, and into each of the large piles at its end; by this means the water is prevented from soaking or making its way, except through the rectangular openings between the several piles, which should be at least as high as the highest floods, and have their tops connected by strong cross pieces of timber bolted on to them; in these cross pieces, and in the sill below, a number of holes are prepared for placing at equal intervals as many upright pieces of wood, called rimers, with rebates in their sides for temporary gates to slide down in, and rest against; after these rimers are put in, a sluice or gate, with a tall handle to rest against the upper or cross piece, is put in between each rimer; and, above these, another set of gates, called over-falls, with similar handles, are fitted, to be occasionally used in dry seasons, when none of the water is to be suffered to escape, except by the side-cut and lock-paddles. In time of floods, all these gates, overfalls, and rimers, are taken away, by persons who go in a boat for that purpose; which operation, we are told, can be performed in three hours, and the water is suffered to take its free course through the openings; as the water subsides, a few of these gates are put in at a time, leaving the water its course through the others, until all of them are in, when on any small rise of the water, the same falls over the tops of these gates into the bed of the river below; when a greater depth of water is wanted above, the over-falls or upper gates are successively put in upon the others; these last being of such a height that the water can fall over their tops before it would overflow the meadows in case of its rising, and the men not attending or being expeditious enough in taking away the over-falls, and then the gates, if the progressive rise of the river should render it necessary.*

* The ice freezes much thicker and longer in our rivers, particularly in the middle and eastern states, than in those of Great Britain. Would not the great masses of ice, drift-wood, &c. which are hurried down, by the impetuosity of our floods at the breaking up of winter, destroy and render useless such improvements as those above mentioned?

In the *Thames* and several other rivers, *Jetties* or *Weir-hedges* have formerly been made, for diminishing the width of the river below the several shoals, in order to make a deeper but narrower and more rapid current over the same, as is done, we are told, on the China canals; but the rapid and dangerous currents which these and the under-water weirs occasion, particularly in high water times, have been so justly and loudly complained of, that we trust the same will, ere long, give place to the side-cuts, pound-locks, and opening-weirs, above described.

For improving the navigation of rapid, confined, and variable rivers, like the *Severn*, Mr. *Thomas Telford*, in *Plymley's Report*, p. 287, has recommended the deepening the lower part of the bed of the river in the shallow places, in order to equalize the declivity and current of the river: a very experienced engineer has suggested, that deepened shallows, without Jetties or similar constructions, would soon be again filled up in many cases. In the higher parts, Mr. *Telford* proposes to erect solid and durable weirs of masonry across the river upon shallow places, with side-cuts and pound-locks by the side of them, for the navigation; and the river when thus diverted, may, as he justly observes, be applied to many important purposes of machinery, and for irrigating of the meadows, which would thus be brought within its reach. There is no doubt but this method is practicable, and would ultimately answer well; but the expense would be very great of erecting substantial weirs, and making the banks of the side-cuts, and walls, and gates of the locks, high enough to prevent the floods from breaking over into them, a condition which seems necessary, if barges are to be able to proceed at all times; the towing-path should also for the same purpose be made up with a regular sloping bank next the river, presenting no inequalities or projecting objects to catch or wear the towing-lines, so that its top or path shall be always above water. On a river which rises 16 or 17 feet or more, these works would be attended with a most serious expense and difficulty, particularly where

cliffs rise almost perpendicularly up from the bed of the stream. Machinery on such a stream, unless great expense indeed was incurred to obviate it, would be subject to have its work interrupted by every large flood: the working of boats on a river with such cuts, locks, and towing-paths, as we have mentioned, would be attended with considerable difficulties; tall masts must be used for attaching the towing-line in dry times to bring the line on a level, or nearly so with the horses, and in floods it must be fixed lower down, or to a shorter mast; and in such cases, the utmost care might not always be able, where the works are necessarily confined by rocky banks, to prevent barges from sometimes missing the entrance of the side-cut, and being precipitated down the current over the wier, and being sunk.

The *heaving of ballast*, as it is called, or the taking up of sand, gravel, or other loose or soft matters from the bottom of rivers, to deepen their beds, or for any other purpose, is usually performed by a strong pole, having a flat ring or hoop of iron fixed on its end, to which a strong leathern bag is fastened, like what is called a landing-net among fishermen; or for taking up gravel only, a fine and strong net is used instead of a leathern bag; the edge of this hoop is made sharp, so as to strike into the bottom, when a man pushes it down by its pole; near to this hoop a rope of considerable length is fastened, which is held by a man that stands at the head on the gunwale of a boat at anchor, while another man at the stern strikes the hoop and bag into the bottom, the man at the head then hauls at the rope to drag the bag along and scrape the bottom, while the other man shoves down the pole to which it is attached, until the bag is filled with sand, gravel or other matters, which are wanted to be got up; the man with the rope then advances nearer to the other, and pulls up by the rope while the other does the same by the pole, and brings the bag over the side of the boat and empties its contents into the same. If the bottom be hard, or the bag large, two or more men are employed to pull the rope, and sometimes a winch and roll on which the rope or chain winds, are

used for dragging the hoop and bag along the bottom, and for hauling the same up to the surface, when the man at the pole finds that the bag is full, he begins to pull instead of pushing by the pole; this is the employment at Woolwich of a great number of convicts, instead of their being transported Solid matters or rocks when they happen to need excavating, below the level that the water can be drawn off to, or the ebb of the tide, seem to require all the skill and resources of the engineer.

It may not be uninteresting to the reader, to learn the opinion which was entertained by the great *Brindley*, (who is emphatically stiled the father of British canals) on the subject of the improvement of river navigation. He was the greatest enthusiast, (says *Phillips*) in favour of artificial navigations that ever existed. "Having spoken upon various circumstances of rivers before a committee of the House of Commons, in which he seemed to treat all sorts of rivers with great contempt, a member asked him for what purpose he apprehended rivers were created? Mr. *Brindley*, considering within himself a moment, replied, "To feed navigable canals," see *Inland Navigation* by *J. Phillips*, pages 113–14.

CHAP. XIV.

WATER-CEMENTS. PUZZOLANA. TARRAS. BLACK OXIDE OF IRON. IRON ORES. WOOD-ASHES. COMPACT BASALT. CENDRÉE DE TOURNAY. LORIOT MORTAR. NOTE, ON WATER CEMENTS BLACK OXIDE OF MANGANESE. MATERIALS IN THE UNITED STATES.

AS the construction of locks requires the use of mortar or cement, which will set, indurate or harden under water; a short account of *Water Cements*, may not be improper. Although a well made mortar, com-

posed merely of sand and lime, if allowed to dry, becomes impervious to water, yet if the circumstances of the building are such as to render it impracticable to keep out the water, whether fresh or salt, a sufficient length of time, the use of common mortar must be abandoned; for lime and sand, if mixed together in any proportions, and put, while soft, into water, will, in a short time fall to pieces.

Among the nations of antiquity the Romans appear to have been the only people who practised building in water, and especially in the sea, to any great extent.—The bay of Baiæ, like our fashionable watering places, was the summer resort of all the wealthy of Rome; who, not content with erecting their villas as near the shore as possible, were accustomed to construct moles, and form small islands, in the more sheltered parts of the bay, on which, for the sake of the grateful coolness, they built their summer houses and pavillions. They were enabled to build thus securely in the water by the fortunate discovery, at the neighboring town of Puteoli, of an earthy substance, which, from this circumstance, was called *fulvis puteolanus*, (powder of Puteoli.)

Puteolan powder, or as it is now denominated puzzolana, is a light, porous, friable mineral, of a red colour, and is generally supposed to derive its origin from concreted volcanic ashes, thrown out from Vesuvius, near to which mountain the town of Puteoli is situated. It seems to consist of a ferruginous clay, baked and calcined by the force of volcanic fire, and when mixed with common mortar, not only enables it to acquire a remarkable hardness in the air, but to become as firm as stone, even under water. The only preparation which puzzolana undergoes, to fit it for use, is that of pounding and sifting, by which it is reduced to a coarse powder; in this state being thoroughly beaten up with lime, either with or without sand, it forms a mass of remarkable tenacity, which speedily sets under water, and becomes at least as strong as good free-stone.

It has been before observed, that a composition of pure lime and sand alone will not harden under water

but limes containing a portion of clay possess this property in a considerable degree, and are therefore generally used in water building. The cement used by Mr. Smeaton, in the construction of the Eddystone lighthouse, was composed of equal parts by measure of slaked Aberthaw lime and puzzolana. The peculiar difficulties of this undertaking, exposed to the utmost violence of the sea, rendered these proportions advisable; but for works that are less exposed, such as locks and basons for canals, &c. the quantity of puzzolana may be considerably diminished. A composition of this kind, which has been found very effectual, is two bushels of slaked Aberthaw lime, one bushel of puzzolana, and three of clear sand; the whole being well beaten together will yield 4.67 cubic feet of cement.

The Dutch have practised building in water to a greater extent than any other nation of modern Europe; and to them is due the discovery of a cement admirably well adapted for this purpose, and called tarras or trass.—This is nothing more than wakke, or cellular basalt, and is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is transported down the Rhine in large quantities to Holland. This substance being, by grinding and sifting, reduced to the consistence of coarse sand, is used in the composition of mortar, with the blue argillaceous lime from the banks of the Scheldt, in the following method. They take of the quick-lime about the quantity which will be wanted during a week, and spread it in a kind of bason in a stratum of a foot thick and sprinkle it with water. It is then covered with a stratum of about the same thickness of tarras, and the whole suffered to remain for two or three days, after which it is very well mixed and beaten, and formed into a mass, which is again left for about two days; it is then taken in small quantities, as it is wanted for daily consumption, which are again beaten previous to using. Thus is composed the celebrated tarras mortar with which the mounds and other constructions for the purpose of protecting the lowlands of Holland against the sea are cemented.

Tarras is frequently used in this country, being imported from Holland for that purpose. The proportions of the materials of the tarras mortar generally used in the construction of the best water works is the same as the Dutch practise. One measure of quicklime, or two measures of slaked lime in dry powder, is mixed with one measure of tarras, and both very well beat together, to the consistence of a paste, using as little water as possible. Another kind, almost equally good, and considerably cheaper, is made of two measures of slaked lime, one of tarras, and three of coarse sand; it requires to be beaten a longer time than the foregoing, and produces three measures and a half of excellent mortar. When the building is constructed of rough irregular stones, where cavities and large joints are to be filled up with cement, the pebble mortar may be most advantageously applied; this was a favorite mode of construction among the Romans, and has been used ever since their time in those works in which a large quantity of mortar is required. Pebble mortar will be found of sufficient compactness if composed of two measures of slaked argillaceous lime, half a measure of tarras, or puzzolana, one measure of coarse sand, one of fine sand, and four of small pebbles, screened and washed.

It is only under water that tarras mortar acquires its proper hardness; for if suffered to dry by exposure to the air, it never sets into a substance so firm as if the same lime had been mixed with good clean common sand, but is very friable and crumbly. Ash mortar is reckoned to be superior for works that are sometimes wet and sometimes dry, but tarras has the advantage when constantly under water. Tarras mortar when kept always wet, and consequently in a state most favorable to its cementing principle throws out a substance something like the concretions in limestone caverns called stalactites, which substance acquires a considerable hardness, and in time becomes so exuberant as to deform the face of the walls.

Although the cellular basalt is the only kind admitted into the preparation of Dutch tarras, yet it appears from some good experiments of Morveau on the subject, that the common compact basalt, if previously calcined, will answer nearly the same purpose.

In some parts of the Low Countries coal ashes are substituted for tarras with very good effect; of which the valuable *Cendrée de Tournay* is a striking instance. The deep blue argillo-ferruginous limestone of the Scheldt is burnt in kilns with a slaty kind of pit-coal that is found in that neighborhood. When the calcination of the lime is completed, the pieces are taken out, and a considerable quantity of dust and small fragments remain at the bottom of the kiln. This refuse consisting of coal ash mixed with about one fourth of lime dust, is called the cendrée, and is made into a mortar with lime in the following method. About a bushel of the materials is put in any suitable vessel, and sprinkled with water just sufficient to slake the lime; another bushel is then treated in the same way, and so on till the vessel is filled. In this state it remains some weeks, and may be kept for a much longer time if covered with moist earth. A strong open trough, containing about two cubic feet, is filled about two thirds full with the cement in the above state, and by means of a heavy iron pestle, suspended at the end of an elastic pole, is well beaten for about half an hour: at the end of this time it becomes of the consistence of soft mortar, and is then laid in the shade from three to six days, according to the dryness of the air. When sufficiently dry, it is beaten again for half an hour as before, and the oftener it is beaten the better will be the cement; three or four times, however, are sufficient to reduce the cement to the consistence of an uniform smooth paste; after this period it is apt to become refractory on account of the evaporation of its water, as no more of this fluid is allowed to enter the composition than what was at first employed to slake the lime. The cement thus prepared is found to posses the singular advantage of uniting in a few minutes so firmly to brick or stone, that still

water may be immediately let in upon the work without any inconvenience, and by keeping it dry for 24 hours, it has nothing further to fear from the most rapid current.

A composition very similar to the preceding in materials, which are coal cinders and lime, though seldom prepared with any attention, is the blue mortar, commonly used in London for setting the coping of buildings, and other works much exposed to the weather.

Ash mortar is used in some parts of England. It is prepared by slaking two bushels of fresh burnt meagre lime, and mixing it accurately with three bushels of wood ashes: the mass is to lie till it is cold, and is then to be well beaten: in this state it will keep a considerable time without injury, and even with advantage, provided it is thoroughly beaten twice or thrice before it is used.

The scales, or black oxyd of iron, which are detached by hammering red hot iron, and are therefore to be procured at the forges and blacksmith's shops, have been long known as an excellent material in water cements; but we believe that Mr. Smeaton was the first person who made any accurate experiments on their efficacy, compared with other substances. The scales being pulverised and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, if employed in the same quantity. Induced by the success of these experiments, Mr. Smeaton substituted roasted iron ore for the scales, and found that this also gave to mortar the property of setting under water; it requires, however, to be used in greater proportions than either tarras or puzzolana; two bushels of argillaceous lime, two of iron ore, and one of sand being carefully mixed, produce 3. 22 cubic feet of cement fully equal to tarras mortar. If the common white lime is made use of, it will be advisable to employ equal quantities of all the three ingredients.

With respect to the water used in the preparation of water cements, that of rivers or ponds where it can be had easily, is to be preferred to spring water; but for

works exposed to the action of the sea, such as piers, light-houses, &c. it is usually more convenient and equally advantageous in other respects to use salt water.

Pumice stone, brick, and tile dust, are also recommended for water cements, but their only advantage seems to be an absorbent quality, which causes the morter made with them to set sooner, and therefore acquire a greater hardness in the same time, than mortar composed of sand and lime alone, for they have no power of hardening under water.

The Loriot mortar is a composition which has acquired considerable celebrity in France, and has been employed in some large works. It was invented about 40 years ago by M. Loriot, who imagines that he has discovered the process used by the Romans. The principle of this invention consists in adding to any quantity of mortar made in the usual way with lime and sand, but prepared rather thinner than usual, a certain proportion of quick-lime, in powder The lime powder being well incorporated with the mortar, the mass heats, and in a few minutes acquires a consistence, equal to the best Paris plaster, and is as dry at the end of two days, as an ordinary cement after several months. It also, when the ingredients are well proportioned, sets without any cracks. The quantity of lime powder to be added varies from 1-4 to 1-8 of the other materials, according to the qualities of the lime; too much burns and dries up the mass, and with too little it loses its peculiar advantages; thus the proportions, a point of the utmost importance, can only be determined by experiment. It is its speedy desiccation which rendered the Loriot mortar useful as a water cement, for under water it has only the common properties of a composition of lime and sand of equal solidity; indeed for this purpose various substances, commonly used in cements, are recommended to be added, such as brick and tile powder, and forge scales. The following is an approved receipt. One measure of bricks exactly pounded, two measures of fine river sand, old slaked lime in sufficient

quantity to make a mortar in the usual manner and sufficiently liquid to quench the lime powder which is added in about the same quantity as the pulverised brick.

NOTE.

In addition to the water-cements above mentioned the compiler takes the liberty of extracting the following, on the subject, from *The Chemical Catechism*, by Samuel Parks, F. L. S. page 425.

"Mix four parts of gray clay, six of the black oxide of manganese, and ninety of good limestone reduced to fine powder; then calcine the whole to expel the carbonic acid. When this mixture has been well calcined and cooled, it is to be worked into the consistence of a soft paste with sixty parts of washed sand. If a lump of this cement be thrown into the water it will harden immediately. Such mortar, however, may be procured at a still less expense, by mixing with common quick-lime a certain quantity of what are called the *white* iron ores, especially such as are poor in iron. These ores are chiefly composed of manganese and carbonate of lime, or chalk."

That all the materials for making the different kinds of water-cements, except puzzolana, and perhaps except cellular basalt, exist in great abundance, in the United States, there cannot be a doubt; and with respect to cellular basalt, with which the Dutch make the celebrated tarras mortar, it is very probable, considering the extent of our country, and the varieties of our soil, climate and mountains, that this also may be found: but the mineralogy of the United States is yet so imperfectly known, that this, at present, must rest in conjecture. We have, however, it is believed, all the kinds of lime-stone; and the State of New-York can furnish the several varieties, from the pure white lime of the bald mountain in Washington County, to the blue argillaceous and gray ferruginous kind, commonly known in the country by the name of *bastard limestone*. It is hardly worth while to remark, that we have forge scales, or the black oxide of iron in almost any quanti-

ties ; and iron ores exist in such abundance, that it would be superfluous to designate the places where they may be found. Several of the States produce pit coal in considerable varieties ; and wood ashes are in great plenty, and of trifling value, in all parts of the country. The writer of this has, in his possession, a good specimen of the black oxide of manganese, brought from Bennington in the State of Vermont, where it is said to exist, in great quantities, and there is but little doubt, that it may also be found in various other parts of the United States. But perhaps the compact basalt would be the cheapest material for a water-cement that could be procured in the State of New-York : and we have enough of this material, in one place, to supply the United States. The well known rocks, or cliffs, called the *Pallissadoes*, which form a part of the west bank of the Hudson river, below the highlands, are entirely composed of compact basalt. This, when burnt like lime, and pulverised, communicates to the mortar with which it is mixed, the property of hardening under water. It may be pulverised by the rolling of a heavy circular stone with a horse, in the same manner as tanners grind bark ; or by the simple hydraulic machine, with which gypsum or plaster of Paris is broken into small fragments before it is ground.

Basaltes or basalt is of a gray, blue, or purplish black color, destitute of lustre or transparency, commonly presenting a texture composed of granular concretions, and is found in large masses of a regular form, generally columnar. According to *Klaproth*, it is composed of 44.5 silex, 7 alumine, 20 oxide of iron, 9.5 of lime, 2.6 of soda, and 6 manganese and water. See *Chemical Catechism* page 438.

CHAP. XV.

SPIRIT LEVEL WITH TELESCOPIC SIGHTS. DESCRIPTION THEREOF. PROVING THE SAME. LEVELLING STAVES. TABLE OF DIFFERENCE BETWEEN APPARENT AND REAL LEVEL.

THE *spirit level with telescopic sights.* A short description of this instrument, as it is generally made is as follows: The *spirit level*, also called the "*air-level*," consists of a cylindrical glass tube filled with spirits of wine, except leaving in it a small bubble of air: its ends are hermetically sealed to keep in the fluid — This bubble being the lightest of the contents of the tube, will, by the laws of hydrostatics, always run towards that end of the tube which is the most elevated; but when the tube is perfectly horizontal, the bubble will have no tendency towards either end. The tube is not strictly cylindrical withinside, though it bears that appearance; it is slightly curved, the convex side being upwards, and by this means the bubble will rest in the middle of the tube when it is horizontal, but approaches either end which is elevated above the other: thus made, it is attached to a brass rule by a proper aparatus.

The *telescope* is in a little brass tube, about fifteen inches long, fastened on the same rule as the *level*, and parallel with it. At one end of the tube of the telescope, enters a little tube carrying the eye-glass and a hair horizontally placed in the focus of the object-glass (and sometimes, also, a perpendicular hair, crossing the horizontal one at right angles, in the centre); which little tube may be drawn out, or pushed into the other, for adjusting the telescope to different distances. At the other end of the telescope is fixed the object-glass: there is a screw for raising or lowering the little fork carrying the hair, and making it agree with the bubble of air when the instrument is level; also, another screw

for making the bubble of air agree with the telescope. The whole is fitted to a ball and socket. These instruments are sometimes made on constructions, different from the above, having a greater complication of screws and other apparatus for adjusting them; they also, sometimes have a surveyor's compass, connected with them.

The first process, preparatory to taking any levels, is to prove the correctness of the instrument you employ for that purpose. Some instruments are contrived to prove themselves; but others require an actual trial on the field, which is a general method and applicable to a level of any kind. If the instrument is made with plain sights, (and without a telescope, as some are,) the proof is very simple: first set it level, and observe through its sights some distant object; then turn the level end for end and observe the same object. If it points the same both ways, it is correct; if not, the level must be altered one half of the difference thus discovered, the error being doubled by this method of trial. For instance, if the instrument pointed below the true level the first time, it will point as much above it when turned end for end. A level with a telescope cannot be used at either end, and therefore this method is inadmissable, and the following may be adopted.

Place the instrument on the margin of a pond or other standing sheet of water of several chains in extent; point the telescope, nicely adjusting the same by the bubble, to some object on the margin of the water, or across, or standing in the same, at eight or ten chains distance: by the help of an assistant mark accurately the place where the cross hairs of the telescope cut the object: measure nicely the perpendicular height of this place above the surface of the water, making a due allowance for the difference between the apparent and real level, of which we shall directly treat; measure also the height of the centre of the telescope above the surface of the water, and if the two measurements agree the instrument is correct; if not, it must be rectified until they agree. The following method, where no standing water is at hand, is equally correct. Choose

a spot of ground where it is tolerably level for 20 chains in extent, and place the instrument at a station which we will call A: direct the telescope to a target held up by an assistant, upon a stake driven down to the surface of the ground at B. twenty chains distant. Your assistant must, according to your signals, elevate or depress the vane of the target, till it appears in the intersection of the cross hairs; now measure and write down the height of the centre of the telescope above a stake previously driven into the ground immediately under it, which, suppose to be four feet; your assistant is also to measure and write down the height at which the vane of the target stands above the stake at B, which, suppose to be six feet; the apparent difference of level between A and B will thus be two feet, B being two feet the lowest. But the line of vision, through the telescope to the target, being a tangent to the earth's surface, the true level will be found by deducting the allowance for 20 chains, shown by the table of the earth's curvature to be 041 of a foot; which will make for the true difference of level between A and B 1.959 feet. To prove this, level it the other way, removing the instrument to B and the target to A. Observe in the same manner as before, and if it gives the same difference of level as before, after deducting the allowance, the instrument is correct; if, on the other hand, the results by the two methods do not prove the same, take half the difference between the two, and elevate or depress the target that quantity, according as the last observation was greater or less than the first, and adjust the instrument, either by the screw under the level, or the screws of the cross hairs until they appear to cut the vane of the target so corrected, when the bubble is in the middle. The instrument is now corrected, but the trial should be repeated to make it certain; the trial should also be often repeated during the operation of levelling for the line of a canal, lest, by the derangement of the instrument, gross errors should be committed.

Levelling staves, are instruments used in levelling; serving to carry the targets, vanes, indexes, or marks to

be observed, and at the same time to measure the heights of those marks from the ground. They are of different constructions, but generally consist of two long square wooden rulers, made to slide over each other, each being something more than five feet long, so that when extended they may form a rod of ten feet in height.—They have a graduated line of feet into inches and tenths, or of feet into hundredths. The index, vane, or target (which may consist of a thin flat piece of wood, or of paste-board, or of tin, five or six inches by three in size, placed so that its length crosses the staff at right angles) slides firmly, and is moved up or down, by signal to any point between the two extremes of the ten feet, by the attendant who carries the staff, till the observer finds it coincide with the intersecting wires or hairs of his telescope. Its height on the staff, of course marks the difference of the level; and it has two horizontal and parallel black stripes (or sometimes a black and white stripe), which, at considerable distances, are of use to direct the eye more readily to its fiducial edge, or to its central line.

In order to understand the difference between the *apparent* and the *true* level, and the reason of making an allowance therefor, in levelling for the line of a canal; it will be necessary to consider, that every sheet of water has a tendency, owing to its fluidity and to the laws of gravitation, to settle and remain at rest, in such a situation, as that every part of its surface will be equidistant from the centre of the earth; and, as the earth is globular, it is evident that the surface of every sheet of still and undisturbed water will present, not a straight, but a curved line, exactly conforming itself to the rotundity of the earth.

One place is said to be higher than another, or *out of level* with it, when it is more remote from the centre of the earth; and a line equally distant from the earth's centre, in all its points, is called *the line of true level*; whence, because the earth is round, that line must be a curve, and make a part of the earth's circumference, or an arc concentrical with it, all the points whereof are equally distant from the centre of the earth.

But the line of sight, which the operations of levels give, (not being a curved but a straight line) is a tangent or a right line perpendicular to the semi-diameter of the earth; one extreme of which tangent being the point of contact, the other will be that of a secant drawn from the centre of the earth: and the point which determines it, will be above the surface of the earth, and of the true level, as much as that secant exceeds the radius, or semi-diameter of the earth. This extremity of the tangent is said to be in the apparent level, as being that given by the sight; but it is easily reduced to the *true* level, because we know by trigonometry, how much each secant exceeds the radius; and because by measuring, we have discovered the precise length of that radius. The rise of the apparent above the true level is always proportional to the square of the distance. It was for want of the knowledge of this, that the ancients were not able to reduce the apparent level to the true one; and accordingly, to avoid error, they never levelled above twenty feet at once, where such reduction was not necessary.

By the table since made, it appears, that at the distance of 100 yards the apparent level is raised above the true one about one third of a line; so that the ancients, in this respect were more scrupulous than needful. By means of this reduction, we are now able to level distances of one or two miles at a single operation, which the ancients could not do in less than three hundred.

A table, from which the following table is extracted, for shewing the height of the apparent level above the true, was calculated by Mr. Ferguson, to the extent of a whole degree of a great circle on the earth's surface, and it agrees so nearly with one of the same sort in Doctor Long's Astronomy, as not to differ quite two inches from it at the end of the whole degree, which contains 60 geographical miles, equal to 69 1-2 English miles — The following table extends to sixty seconds or one geographical mile, the same being 6094 feet, whereas an English mile is 5280 feet. The second column which contains the distance may be reduced to chains and links or to rods, yards, or other denomination, as convenience may require.

A TABLE, shewing the height of the apparent level above the true, at any distance within one minute of a degree of a great circle on the earth's surface; calculated to the 1000dth part of an inch.

If the distance of the object from the place of the spectator be	Seconds.	which measured in a great circle upon the earth, amounts to Feet.	Inches.	the height of the apparent level above the true will be Inches.
	1	101	6.8	0.003
	2	203	1.6	0.012
	3	304	8.4	0.027
	4	406	3.2	0.047
	5	507	10.0	0.074
	6	609	4 8	0.106
	7	710	11.6	0.145
	8	812	6.4	0 189
	9	914	1.2	0 239
	10	1015	8 0	0 295
	11	1117	2 8	0.357
	12	1218	9.6	0 425
	13	1320	4 4	0 499
	14	1421	11.2	0 579
	15	1523	6 0	0.665
	16	1625	0.8	0 756
	17	1726	7.6	0.854
	18	1828	2 4	0.947
	19	1929	9 2	1 067
	20	2031	4 0	1 182
	21	2132	10.8	1.303
	22	2234	5 6	1.420
	23	2336	0 4	1.563
	24	2437	7.2	1.702
	25	2539	2 0	1 847
	26	2640	8.8	2 001
	27	2742	3 6	2 154
	28	2843	10.4	2 316
	29	2945	5 2	2 485
	30	3047	0 0	2 659

TABLE *continued.*

If the distance of the object from the place of the spectator be	Seconds.	which measured in a great circle upon the earth, amounts to Feet.	Inches.	the height of the apparent level above the true will be Inches.
	31	3148	6 8	2 839
	32	3250	1 6	3.026
	33	3251	8 4	3 218
	34	3453	3 0	3 416
	35	3554	10 0	3.619
	36	3656	4 8	3.829
	37	3757	11.6	4 045
	38	3859	6.4	4.267
	39	3961	1.2	4.494
	40	4062	8.0	4.728
	41	4164	2.8	4.967
	42	4265	9 6	5 212
	43	4367	4.4	5 463
	44	4468	11 2	5 720
	45	4570	6 0	5.983
	46	4672	0 8	6.252
	47	4773	7.6	6 527
	48	4875	2 4	6 808
	49	4976	9.2	7.094
	50	5078	4.0	7 387
	51	5179	10 8	7 685
	52	5281	5.6	7 989
	53	5383	0 4	8 300
	54	5484	7.2	8 616
	55	5586	2 0	8 938
	56	5687	8 8	9 265
	57	5789	3.6	9 660
	58	5890	10 4	9 940
	59	5992	5.2	10 285
	60	6094	0 0	10 637

CHAP. XVI.

ESTIMATE OF EXPENSES OF THREE SEVERAL CANALS AND THEIR APPENDAGES. CANALS OF HOLLAND, THEIR SIZE. EXPENSE OF LOCKS AND INCLINED PLANE COMPARED. RELATIVE PROPORTIONS OF CANALS. DAY'S WORK OF EXCAVATION IN CUBIC YARDS. REMARK ON THE CANAL FROM CARDIFF TO MERTHIR-TIDVIL.

IN order to give the American reader an idea of the expense of making canals in Great Britain, and of the mode adopted by engineers, of calculating that expense; the following estimates are introduced from "Inland Navigation" by *J. Phillips*, pages 159—60—61 62—63—64; and also some miscellaneous remarks from the same author pages 584—5.

"The estimate of making the Canal from or near Tern-Bridge, on the River Severn, in the county of Salop, to the Junction at Bridgeford, in the County of Stafford: the distance being 31 1-4 miles. Rise 136 feet 9 inches to the summit. Fall to Bridgeford-Bridge 54 feet 8 inches:

In the intended course of this canal, between the upper end of Tunstall Moors, (in the valley below Offley Park), and its junction with a brook near to Cockmere: the distance being a mile and a half: the highest point of land being 25 feet high. To reduce this to a level 18 yards in width, (being the breadth of the towing-path, canal, and drains) must be removed at a mean 198015.84 cubic yards, which, at 3 *d.* per yard, will amount to - - - - - -	£2,475	5	11 1-2

The canal is proposed to be 9 yards broad at the surface of the water, and 6 yards broad at the bottom. These dimensions, in 31 1-4 miles, will produce 687637.5 cubic yards, to be removed, which, at 3 *d.* per yard, will amount to - - - - - -	8,595	9	4 1-2
The canal, towing-paths, and drains, being 18 yards in breadth, in 31 1-4 miles (deducting one mile for waste land), there will be 199 A. 1 R. 20 P. to purchase which, at 15*l.* per acre at a mean, will amount to - -	2,985	0	0
Twenty road bridges, at 80*l.* each, will be - - - - - -	1,600	0	0
Fifteen water bridges, at 50*l.* each, will be - - - - - -	750	0	0
Making towing paths, drains, gates, and fencing, at 10*l.* per mile - -	312	10	0
From the highest point of land below Offley Park to the river Severn (the fall being 136 feet 9 inches), supposing a lock necessary for every fall of 10 feet, 13 locks will be required, which, at 450*l.* per lock, will amount to - - - - - - -	5,850	0	0
From the said highest point to Bridgeford-bridge (the falls being 54 feet 8 inches), in the abovementioned proportion, there must be at least five locks, which at 450*l.* each, will amount to - - - - - - £	2-250	0	0
Two funnels between each lock, making 34 in number, at 10*l.* each, will amount to - - - - -	340	0	0
Five per cent. upon the whole for unforeseen accidents - - -	1,414	3	0
	£26,572	6	4

" The estimate of the expense of making the Junction above Bridgeford-Bridge, in the county of Stafford, to Winsford-Bridge, in the county of Chester. The distance 32 3-4 miles. Rise to the summit 100 feet 3 1-4 inches. Reduced fall to Winsford-Bridge, 284 feet 1 inch :—

In the intended course of this canal, between the lower end of Charlton Moss, and about half a mile below Snape, the distance being one mile and half, the highest summit of land is an elevation of 25 feet. To reduce this to a level, 18 yards in breadth, which is the breadth of the canal, towing-paths, and drains, must be removed at a mean 19801584 cubic yards, which, at 3*d.* per yard, amounts to - - - - - -	£2,475	3	11 1-2
The canal is proposed to be nine yards broad at the surface of the water, and six at the bottom, and five feet deep. These dimensions, in 32 3-4 miles, will produce 72011.8 cubic yards of earth to be removed, which, at 3*d.* per yard, will cost - -	9,002	13	0
The canal, towing-paths, and drains, at 32 3-4 miles, there will be to be purchased 214 acres, which, at 20*l.* an acre, will amount to - -	4,287	5	2 1-2
Twenty-two road bridges, at 80*l.* each - - - - -	1,760	0	0
Three water bridges, at 50*l.* each	150	0	0
Making towing-paths, back-drains, gates, and fencing, at 10*l.* per mile, amounts to - - - - -	£330	0	0
From the junction above Bridgeford, to the summit in Madeley Park, 100 feet 3 1 4 inches, supposing a lock at every 10 feet necessary, it will require ten locks, at 450*l.* each,	4,500	0	0

From the above summit to Winsford-bridge, 284 feet, 1 inch fall; and supposing as above, it will want 28 locks, at 450*l.* each,	12,600	0	0
Two funnels between each lock, will be 76, at 10*l.* each,	760	0	0
Five per cent. upon the whole for unforeseen accidents	1,798	5	0
Total	£37,658	7	2

"The estimate of making the canal from the junction of the River Sow, above Bridgeford to Burton, in the county of Safford; and thence to Wilden Ferry, the distance being 27 miles to Burton, and 16 from thence to Wilden Ferry. Fall to Wilden Ferry is 209 feet 4 inches:—

The canal is to be nine yards broad at the surface of the water, six yards at the bottom, and five feet deep: these dimensions in 43 miles will produce 945621 6 cubic yards, which, to remove, at 3*d.* per yard, amounts to	£11,820	5	4
The canal, towing-paths and drains, 18 yards wide, and 43 miles long, there will be 281 acres and 2 roods, which, at 30*l.* per acre, comes to	8,415	0	0
From the above junction to Wilden Ferry, is 209 feet 4 inches fall, which will require a lock every 10 feet, will be 21 locks, at 450*l* each,	9,450	0	0
Two funnels between each lock are required, which make 52, at 10*l.* each, and amount to	520	0	0
Thirty-six road bridges, at 80*l.* each,	2,880	0	0
Seven water bridges, at 50*l.* each,	350	0	0
Towing-paths, back drains, and			

fencing, at 10*l.* per mile, for 43 miles, is - - - - - - -	430	0	0
Five per cent. upon the whole for unforeseen accidents - - -	1,677	5	0
Total	£35,572	10	4

In treating of the canals of Holland, I have observed that the sagacious Hollander does not make his canals all of one size or dimension, but proportions them to their respective traffic. Thus I have there instanced one mile of canal whose square surface does not exceed two acres of land, and which yearly netts 625*l.* On these canals barges are used, even so small as 5 or 6 tons each.

According to the general application to the British parliament for canals, the people of this country seem to covet them all of the same size, as if all were intended for business on an equal scale. On the contrary, we should imitate the thrifty Dutchman in having some smaller canals, and smaller barges of 5 to 12 tons each, which would answer all purposes for short or cross navigation, and would not only take up less land, but would be made at much less expense; and I should suppose that a barge of 4 or 5 feet wide, 20 to 25 feet long, and 2 1-2 to 3 feet deep, carrying 6 to 8 tons, would be sufficient for such purposes.

The inclined plane, instead of locks, was first noticed by me in the description of the Chinese method, in my quarto volume; and I am very happy to find that several very eminent engineers have made a considerable improvement on it, and among them the ingenious Mr. Fulton.

I shall not enter into an argument with Mess. Fulton, Tatham, and Chapman on the inclined plane, which they have separately treated on at large, it being foreign to my present abridgement, but it may not be improper just to notice, in as short a manner as possible,

Mr. Fulton's statement of different costs in the old lock system, (as he calls it) and the plane in rising 100 feet.

The usual expense of locks, he says, for 25 ton boats is 70*l.* per foot, and for 40 ton boats, 100*l.* per foot, which in the first case will cost 7000*l.* and in the second 10,000*l.* Now his plane on an angle of 20 deg. will cost only 2294*l.* 14*s.* consequently a saving in the first instance of 4705*l.* 6*s.* and in the second instance 7705*l.* 6. The particulars of the expense of erecting the inclined plane are needless here, as Mr. Fulton has particularly inserted it in his book, but he also observes, in the case of a trade totally descending, the loaded boats raising those that are empty, the tub-pit, the drum, wheel, and all that part of the machine for creating power may be saved, amounting to 1191*l.* the contingent expenses being likewise reduced in proportion, in which case a double inclined plane to the height of 100 feet would cost only 1655*l.* 16*s.* and by this machine, in the descending trade, 800 tons will be done in 12 hours.

On the Grand Trunk Canal it takes generally five minutes to pass an 8 feet lock, which, to rise 100 feet at that rate, will be 63 minutes. Mr. Fulton says he can pass the 100 feet in height by his double plane in four minutes.

A canal 60 feet wide at top and 5 feet deep, formed on an angle of 78 deg. will be 47 feet wide at bottom, and the digging will be 30 cubic yards of earth for one yard running measure.

The canal from Cardiff to Merthir-Tidvil is completed, and a fleet of canal boats have arrived at Cardiff laden with the produce of the iron-works there, to the great joy of the whole town. The rude tracks, through which the canal passes in some places are constantly improving, from the happy and healthful toil of the husbandman, and in a few years will be forgotten in a garden of verdure and fertility. This canal is 25 miles long; it passes along the sides of stupendous mountains. Nothing appears more extraordinary than, from a boat navigating this canal, to look down on the river Taaff, dashing among the rocks 100 yards below. The

fall from Merthir-Tidvil to Cardiff is nearly 600 feet. The first barge that arrived at Cardiff was finely decorated with colors, and was navigated from the Mollingriffield works by Mr. Bird, sen. water-bailiff of Cardiff.

CHAP. XVII.

MISCELLANEOUS PARTICULARS OF INFORMATION, RESPECTING THE MIDDLESEX CANAL NEAR BOSTON, IN THE STATE OF MASSACHUSETTS.

THE following information and particulars respecting the Middlesex canal, were obtained in the spring of 1816, by two of the commissioners, previously appointed by the Legislature of the State of New-York to explore the route of the Great Western and the Northern canals in that State, who visited and carefully examined the Middlesex canal throughout its whole extent, and committed to writing on the spot the result of their own observations as well as the answers to all their enquiries, which were obligingly given by the very intelligent agent *(Mr. Sullivan)* of the canal company.

The canal is 27 miles long, and connects the tide-water, in Boston harbor at Charleston, with the Merrimack river. The water in the canal is 30 feet wide at its surface, 20 feet at its bottom, and 3 feet deep. The Concord or Sudbury river crosses the line of the canal on the summit-level, 22 miles from Charleston, and 5 miles from the junction of the canal with the Merrimack, and wholly supplies it with water for locking down each way from the summit-level. From tide-water to the summit-level is an ascent of 104 feet, and from thence to the Merrimack a descent of 32 feet. There are, in all, 20 locks of different lifts, of which

the highest is 12 feet. These locks are 75 feet long in the clear, 10 feet wide at the bottom, and 11 feet at the top.

Boats for the transportation of merchandize and produce carry 14 tons and are drawn by one horse the whole length in 5 hours coming down, and in 7 hours going up. To each boat there are 3 men; 2 however, are sufficient to manage the boat on the canal, the other being wanted only on the Merrimack river. From the summit-level down the canal there is a current which exceeds in no place half a mile per hour, there being a fall or descent in the canal of one inch per mile. The expense of transporting a ton the whole length of the canal is $3 50, of which sum $1 70 is toll, and $1 80 is freight.

Across the canal there are 50 bridges made by the canal company; they consist of two stone abutments (one on each side of the canal) 20 feet apart: from one of these abutments to the other, are laid sills or string-pieces of wood covered with plank, and of sufficient height for the towing horses to pass under. The towing-path under the bridges occupies 6 or 7 feet.

Two miles from the lower end of the canal, Mystick river, a turnpike road, and the canal run a little distance parallel with each other, the road being between the canal and river. Here, is afforded a good opportunity of comparing the relative advantages of these three modes of conveyance.

Heavier boats than those above mentioned, are used on the canal for transporting fire wood, lumber, &c.; they are shaped like a scow, are 75 feet long, 9 1-2 feet wide, and carry 25 tons of wood.

The towing-path is generally 8 feet wide so that horses and oxen may easily pass each other. On the opposite side of the canal where a towing-path is not wanted, the upper surface of the bank or embankment is 5 feet wide, and this is found to be sufficient. A branch-canal, or side cut is made to connect the main canal with Mystic river near Medford; this is owned

by a separate company, and is principally used for transporting timber to Medford for ship-building.

The Canal company was incorporated in 1789 and the next year commenced the work of making the canal. When the canal was begun the price of labor by the month was $8. The canal was opened for use in 1804, tho' not completed in 1808, when Mr. Sullivan took charge of it. Some repairs and new constructions have been made every year since. In assessments upon the proprietors, there has been laid out on the canal $528,000 and about 50,000 more, derived from tolls, has been expended in buildings, wharves, &c. At Medford is a swivel bridge which is found to be very inconvenient. The principal articles transported on the canal are wood, timber, lumber of all kinds, pot and pearl ashes, rye, oats, provisions, and building stone from the Merrimack to Boston. Last year 12,000 cords of wood were transported down the canal, and there are more tons of timber in rafts brought down, than of wood.

More than one half of the whole length of the canal is more or less embanked or raised above the natural surface of the ground. Above Medford is an aqueduct across the Mystick river, of which the abutments are 100 feet apart, and between them are three stone piers, each 8 feet thick for supporting the aqueduct. The tide flows up the Mystick river above this place. The surface of the water in the aqueduct, is 10 feet above the surface of the water in the river below, at high water. This aqueduct consists of a kind of trough made of timber and plank which has stood 16 years, but is beginning to decay. The timber is framed together in the usual way of carpenter's work by tenants and mortises, and strengthened by braces. As tenants soon rot and give way, it might have been made on a better and more durable construction with knees and bolts in the manner of ship building. At the upper end of the aqueduct, is a lock of 12 feet lift.

Mr. Weston an English engineer took the levels of the whole length of the line of this canal, part of the

way on two routes. He estimated the expense of making it at £100,000 sterling. The company went on to make the canal without any further aid from any European engineer, and found Mr. *Weston's* levels to be correct.

Over Syms' river is an aqueduct, of which the abutments are 120 feet apart, with three intervening piers. The water in the aqueduct is 30 feet higher than the water in the stream below. These aqueducts all afford convenient waste-weirs. When the water is not drawn off from the canal at the commencement of winter, the expansion of its freezing spreads and injures the timbers of the aqueducts; wherefore it is the practice just before winter sets in, to draw off about one third of the water.

Half a mile above the last mentioned aqueduct is deep-cutting 40 rods in length through loose sand and gravel. In the deepest part the excavation is 20 feet below the natural surface of the earth; and the part excavated is here, from 90 to 100 feet in width at the top. The earth was chiefly carried away in wheel-barrows, some in carts, to an embankment just above, on the right side. Half a mile higher up, the earth is very porous, and on the right side, the water leaks out through or under an embankment: this might have been prevented by putting 2 or 3 feet of water-tight stuff in the bottom of the canal.

Near this place are two water-gates by which the water of the canal is drawn off in the spring for the purpose of clearing out the earth, stones, &c. which fall into it and injure the navigation. The expense of this, is perhaps $500 a year.

Mr. *Sullivan* states that he has had a steam boat on the Merrimack river for the purpose of towing boats; he found that a man by a rope could easily hold a boat in tow immediately astern of the steam boat, which, it would require a horse on the bank of the river, to tow with the same velocity: such, in his opinion, is the great diminution of the resistance of the water to the head of a boat which is drawn in the wake of another boat.

For some weeks in the spring the canal leaks much more than it does the remainder of the season : this is because the banks had been recently swelled and loosened by the action of the frost. Three men with a horse and boat are, in the summer constantly employed to keep the banks and particularly the towing-path in order.

The lands within six miles of the canal on each side, have increased one third in price ; while land in the country generally retains its former value. In the State of New-Hampshire, through which the Merrimack flows, timber is now worth from 1 to 3 dollars per ton standing ; before the canal was made it was worth nothing ; so that in the article of timber alone that State is supposed to have been benefitted to the amount of at least 5,000,000 of dollars. The wood-land there, has risen in price, since the opening of the canal, from $2 per acre to $6, $8 and $10 per acre.

In Woburn, a pretty high embankment, which was made in the winter, across a marsh, sunk down in the spring at the breaking up of the frost, so that its top was just level with the natural earth : another embankment was then raised upon it. Near this place the canal, by a deep-cutting of 25 feet, passes through a hill. An embankment at Maple meadow in the town of Wilmington is near 80 rods long and 25 feet high to the top of the towing-path. At a place called the sinking meadow in the above named town, an embankment is made across a marsh of about 30 rods in extent. When this embankment was commenced, it was found that the dirt and stuff carried on to form the embankment kept gradually sinking into the marsh ; when measures were taken to ascertain how much it would sink : the laborers continued to carry on stuff which gradually went down until the whole embankment sunk to the depth of 60 feet ! The great expense of making this embankment across the marsh might have been foreseen and prevented. The depth and softness of the marsh might have been ascertained by souding it with an iron rod, and by conducting the canal circuitously a-

round its margin, a solid foundation might have been secured.

By the act of incorporation, the Legislature authorized the company to occupy 5 rods of land in width on one side of the centre of the canal, and 3 rods on the other. If the owners of the land did not apply for pay within a year, it was deemed a donation. In the statement of monies expended, before made, are included the costs of several law-suits, the building of boats, of offices, the purchase of 70 acres of land, and the erection of mills at Billerica. The land and mills cost $10,000. There is no income derived from hiring out water privileges for hydraulic operations. The canal receives its whole supply of water from the Concord river; and if any were let out for hydraulic purposes, a current would be created, the inconveniencies of which would probably more than counterbalance all the advantages of income.

Either through design or accident, logs, stumps and sticks were in some places left in the banks when the canal was made; and there, having now become rotten, leave unsound places through which the water escapes. A great part of the canal was made by contractors in small parts or jobs, and where two jobs of embankment met each other, the workmen did not, in some cases, take the precaution to prevent the stones, as they threw on the stuff, from rolling down together from each end of the separate job, and thereby forming a loose porous and leaky place in the embankment.

The aqueduct over the Shawsheen river is, between the abutments, 140 feet. The water in it, is 35 feet higher than the surface of the river below. This aqueduct has been made 20 years; it is, like the other aqueducts on this canal, made of wood, and is so much decayed as to require temporary props to support it.—There are three piers between the abutments, and, between the outside pier and the abutment on each side, there is a kind of wooden pier. On the inside or river side of both the abutments, and on both sides of the piers, at suitable distances, large horizontal timbers are

embedded which serve to support the lower ends of the aqueduct braces: when these timbers become rotten the stone work will probably fall down. From each end of this aqueduct to the distance of 500 feet is an embankment nearly 35 feet high.

During the war, the timber used to repair the Constitution Frigate was brought down the canal to Boston, and that used to build the Independence seventy-four, except the live oak, was procured through the same channel, as also were many of the masts and spars, &c. which were furnished at Boston to our vessels of war. Without the canal, this part of the country could not have supplied these necessary articles.

In approaching the Concord river, the canal passes through half a mile of deep-cutting, 800 feet of which is excavated by blasting through a hard granite rock.—In some places, this blasting was carried 7 feet into the rock and from 14 to 20 feet wide. The deep-cutting for this half mile, is from 12 to 20 feet.

Across the Concord river, a few rods below the line of the canal, a dam 150 feet long and 8 feet high is made. This, creates a pond out of which, through the deep-cutting last mentioned, the water flows and supplies the canal 22 miles to Charleston at the tide-water. From the other side of the pond the water flows through the canal 5 miles to the Merrimack river. The water which supplies the 22 miles of canal passes through a horizontal aperture of 6 feet by 1, with a head of 2 feet water above the upper side of the aperture. The towing-path is carried across the pond by means of a floating bridge; a part of which, is occasionally drawn up to let the logs, timber and drift-wood which collect above pass through. There are two waste-gates in the dam, by which the height of the water in the pond can, in some measure, be regulated.

In Chelmsford, within 60 rods of the Merrimack, is an aqueduct, of which the abutments are 110 feet apart, and there are 10 wooden piers to support it. The water in the aqueduct is 16 feet higher than the stream below. Between this aqueduct and the Merrimack is a

fall of 32 feet, and 3 locks of durable stone masonry in tarras mortar. Where the canal joins the Merrimack, a bason is excavated 10 or 12 feet below the natural surface of the earth, and 5 feet below the surface of the river at low water. The extent of the bason is about 200 feet on the shore of the river, and half that distance on a line at right angles with the shore, being nearly semi-circular. There are in all 7 aqueducts on the canal, but those not mentioned above are very inconsiderable: there are also several culverts.—Grass grows in the bottom of the canal and obstructs the passage of the water in autum to such a degree, that at the lower end of the canal 22 miles from its source, the water is sometimes 9 inches lower than it otherwise would be. To remedy this inconvenience a man is employed, who wades along the canal and mows off the grass under water with a scythe. During the winter season while the canal was not used, the musk-rats would sometimes burrow into and endanger the breaking of the banks; in consequence of which the company had offered a bounty of 50 cents for every one that should be destroyed within a certain distance from the canal. This bounty had caused their destruction to such an extent that very little apprehension was entertained of their doing injury.

It was the original design of the company to employ three officers on the canal, viz. a Superintendant, a Treasurer and Clerk; but that project has been abandoned, and those three officers are now united in Mr. Sullivan. His compensation is a salary of $1500 a year, besides 5 per cent on all the tolls or receipts, which are warranted not to fall short of $20,000 per annum.

The receipts of the company from the canal are rapidly increasing. The income in 1808, was $7000. in 1809, $9000, in 1810, $14,000, in 1811, $17,000, last year $25,000, and this year (1816) it will undoubtedly exceed $30,000.

REPORT

OF THE

SECRETARY OF THE TREASURY,

ON THE SUBJECT OF

PUBLIC ROADS

AND

CANALS:

MADE

IN PURSUANCE OF A RESOLUTION OF

SENATE, OF MARCH 2d, 1807.

IN SENATE

OF

THE UNITED STATES.

JANUARY 15th, 1816.

On motion of Mr. Horsey,

Resolved, That eight hundred copies of the following papers, relative to public roads and canals, be printed, for the use of both Houses of Congress, viz.

A resolution of the Senate of the 2d of March, 1807.
A letter from the Secretary of the Treasury.
Report of the same.
Mr. Latrobe's communication marked E.
Mr. Fulton's letter marked F.

Attest,

CHARLES CUTTS, *Secretary*.

In Senate of the United States,

March 2d, 1807.

Resolved, That the secretary of the treasury be directed to prepare, and report to the senate, at their next session, a plan for the application of such means as are within the power of congress, to the purposes of opening roads and making canals; together with a statement of the undertakings of that nature, which, as objects of public improvement, may require and deserve the aid of government; and also a statement of works of the nature mentioned, which have been commenced, the progress which has been made in them, and the means and prospect of their being completed; and such information as, in the opinion of the secretary, shall be material, in relation to the objects of this resolution.

Attest,

SAMUEL A. OTIS, *Secretary.*

Treasury Department,

April 4th, 1808.

SIR,

I have the honour to transmit a report respecting roads and canals, prepared in obedience to the resolution of the senate of the 2d of March, 1807. It has been unavoidably delayed much later than was desirable, or had been expected. Although early steps had been taken for obtaining the necessary information, the most important documents were not received till long after the commencement of this session; some, indeed, within the last ten days. To analyze the whole, to select, arrange, and condense the most interesting facts, was also a work of some labour. Time has not permitted to present the report in a more satisfactory form: but the mass of facts which has been collected will, it is hoped, be of some public utility.

I have the honour to be,
With great respect,
Sir,
Your most obedient servant,
ALBERT GALLATIN.

The honourable George Clinton,
President of the Senate.

REPORT, &c.

The Secretary of the Treasury, in obedience to the resolution of the Senate of the 2d of March, 1807, respectfully submits the following report on roads and canals.

THE general utility of artificial roads and canals, is at this time so universally admitted, as hardly to require any additional proofs. It is sufficiently evident, that whenever the annual expense of transportation on a certain route, in its natural state, exceeds the interest on the capital employed in improving the communication and the annual expense of transportation, (exclusively of the tolls,) by the improved route, the difference is an annual additional income to the nation. Nor does, in that case, the general result vary, although the tolls may not have been fixed at a rate sufficient to pay to the undertakers the interest on the capital laid out. They, indeed, when that happens, lose; but the community is nevertheless benefitted by the undertaking. The general gain is not confined to the difference between the expenses of the transportation of those articles which had been formerly conveyed by that route, but many which were brought to market by other channels, will then find a new and more advantageous direction; and those which, on account of their distance or weight, could not be transported in any manner whatever, will acquire a value, and become a clear addition to the national wealth. Those and many other advantages have become so obvious, that in countries possessed of a large capital, where property is sufficiently secure to induce individuals to lay out that capital on permanent undertakings, and where a compact population creates an extensive commercial intercourse, within short distances,

those improvements may often, in ordinary cases, be left to individual exertion, without any direct aid from government.

There are, however, some circumstances which, whilst they render the facility of communications throughout the United States an object of primary importance, naturally check the application of private capital and enterprise, to improvements on a large scale.

The price of labour is not considered as a formidable obstacle, because whatever it may be, it equally affects the expense of transportation, which is saved by the improvement, and that of effecting the improvement itself. The want of practical knowledge is no longer felt: and the occasional influence of mistaken local interests, in sometimes thwarting or giving an improper direction to public improvements arises from the nature of man, and is common to all countries. The great demand for capital in the United States, and the extent of territory compared with the population are, it is believed, the true causes which prevent new undertakings, and render those already accomplished less profitable than had been expected.

1. Notwithstanding the great increase of capital during the last fifteen years, the objects for which it is required continue to be more numerous, and its application is generally more profitable than in Europe. A small portion, therefore, is applied to objects which offer only the prospect of remote and moderate profit. And it also happens that a less sum being subscribed at first than is actually requisite for completing the work, this proceeds slowly; the capital applied remains unproductive for a much longer time than was necessary, and the interest accruing during that period becomes, in fact, an injurious addition to the real expense of the undertaking.

2. The present population of the United States, compared with the extent of territory over which it is spread, does not, except in the vicinity of the sea-ports, admit that extensive commercial intercourse within

short distances, which, in England and some other countries, forms the principal support of artificial roads and canals. With a few exceptions canals, particularly, cannot in America be undertaken with a view solely to the intercourse between the two extremes of, and along the intermediate ground which they occupy. It is necessary, in order to be productive, that the canal should open a communication with a natural extensive navigation which will flow through that new channel. It follows, that whenever that navigation requires to be improved, or when it might at some distance be connected by another canal to another navigation, the first canal will remain comparatively unproductive, until the other improvements are effected—until the other canal is also completed. Thus the intended canal between the Chesapeake and Delaware will be deprived of the additional benefit arising from the intercourse between New-York and the Chesapeake, until an inland navigation shall have been opened between the Delaware and New-York. Thus the expensive canals completed around the falls of Potomac will become more and more productive, in proportion to the improvement, first of the navigation of the upper branches of the river, and then of its communication with the western waters. Some works already executed are unprofitable, many more remain unattempted, because their ultimate unproductiveness depends on other improvements, too extensive or too distant to be embraced by the same individuals.

The general government can alone remove these obstacles.

With resources amply sufficient for the completion of every practicable improvement, it will always supply the capital wanted for any work which it may undertake, as fast as the work itself can progress, avoiding thereby the ruinous loss of interest on a dormant capital, and reducing the real expense to its lowest rate.

With these resources, and embracing the whole Union, it will complete, on any given line, all the improvements, however distant, which may be necessary to render the whole productive, and eminently beneficial.

The early and efficient aid of the federal government is recommended by still more important considerations. The inconveniences, complaints, and perhaps dangers, which may result from a vast extent of territory, can no otherwise be radically removed, or prevented, than by opening speedy and easy communications through all its parts. Good roads and canals will shorten distances; facilitate commercial and personal intercourse; and unite, by a still more intimate community of interests, the most remote quarters of the United States. No other single operation within the power of government can more effectually tend to strengthen and perpetuate that union, which secures external independence, domestic peace, and internal liberty.

With that view of the subject, the facts respecting canals, which have been collected in pursuance of the resolution of the senate, have been arranged under the following heads:

1. Great canals, from north to south, along the Atlantic sea coast.
2. Communications between the Atlantic and western waters.
3. Communications between the Atlantic waters and those of the great lakes, and river St. Lawrence.
4. Interior canals.

GREAT CANALS ALONG THE ATLANTIC SEA COAST.

The map of the United States will show that they possess a tide-water inland navigation, secure from storms and enemies; and which, from Massachusetts to the southern extremity of Georgia, is principally if not solely interrupted by four necks of land. These are the isthmus of Barnstable; that part of New-Jersey which extends from the Raritan to the Delaware; the peninsula between the Delaware and the Chesapeake; and that low and marshy tract which divides the Chesapeake from Albermarle Sound. It is ascertained that

a navigation for sea vessels, drawing eight feet of water, may be effected across the three last; and a canal is also believed to be practicable, not perhaps across the isthmus of Barnstable, but from the harbour of Boston to that of Rhode-Island. The Massachusetts canal would be about twenty-six; the New Jersey about twenty-eight; and each of the two southern about twenty-two miles in length; making, altogether, less than one hundred miles.

Should this great work, the expense of which, as will hereafter be shown, is estimated at about three millions of dollars, be accomplished, a sea vessel, entering the first canal in the harbour of Boston, would, through the bay of Rhode-Island, Long-Island Sound, and the harbour of New-York, reach Brunswick on the Rariton; thence pass through the second canal to Trenton on the Delaware, down that river to Christiana or New-Castle, and, through the third canal, to Elk River and the Chesapeake; whence, sailing down that bay and up Elizabeth River, it would, through the fourth canal, enter the Albermarle Sound, and, by Pamptico, Core, and Rogue Sounds, reach Beaufort and Swansborough in North-Carolina. From the last mentioned place the inland navigation, through Stumpy and Toomer's Sounds, is continued, with a diminished draft of water, and by cutting two low and narrow necks, not exceeding three miles together, to Cape Fear River; and thence, by an open but short and direct run along the coast, is reached that chain of islands between which and the main the inland navigation is continued to St. Mary's along the coast of South-Carolina and Georgia. It is unnecessary to add any comments on the utility of the work, in peace or war, for the transportation of merchandize or the conveyance of persons.

The several papers under the letter (A) herewith transmitted, contain the information which has been received on those several intended communications. The substance will now be stated.

I. *Massachusetts Canal.*

1. Sandwich isthmus, between Barnstable Bay on the north, and Buzzard's Bay on the south, had first attracted the public attention. Surveys and levels were taken for the purpose of ascertaining the practability of opening a cross cut, to be supplied by the sea itself, from the mouth of Back River, in Buzzard's Bay, to the mouth of Scusset River, in Barnstable Bay.

The distance was found to exceed seven miles; the elevation of the highest intermediate ground is forty feet above low-water mark in Barnstable Bay; the depth of water at the mouth of Back River does not at low water exceed seven feet and a half; and the channel to that spot through Buzzard Bay is obstructed by shoals. The tide, which rises but three feet and a half in that bay, rises three hours and a half later and more than eighteen feet in that of Barnstable. The shore on which that formidable tide would operate is an open beach, without any harbour or shelter whatever. Independent of other obstacles, it was apprehended that the same natural causes which had formed the isthmus might fill the canal or make a bar at its entrance, and the project seems to have been abandoned.

2. The ground was also examined between Barnstable harbour on the north, and Hyannus harbour on the south, at some distance east of Sandwich. The breadth of the peninsula does not exceed here four miles and a half, and there would be an harbour at each end of the canal. The same difference exists in the tides, which rise four feet in Hyannus, and sixteen feet in Barnstable harbour. The entrance of this is obstructed by shoals; but the great obstacle to a cross cut is the elevation of the intermediate ground, estimated at eighty feet above tide water. Navigable ponds on that high ground might perhaps form part of a lock canal and supply the remainder with water. But a canal frozen in winter would not have effected the great object in view, which was to enable vessels from sea to proceed in winter from Matthias Vineyard to Boston, without sailing around Cape

Cod. Although the difficulty of the navigation from Boston to Barnstable diminishes the utility of this communication, as one of the great links in this line of inland navigation, it may be resorted to should that which will be next mentioned prove impracticable for sea vessels.

3. The attention of the legislature of Massachusetts, under whose authority the grounds at Sandwich and Barnstable had been examined, has lately been turned to a direct communication between Weymouth landing, within the harbour of Boston and Taunton River, which empties into the bay of Rhode-Island. A favourable report has been made during the last session, of which a copy has lately been obtained

The distance from tide water to tide water is 26 miles by one route, and 23 1-4 miles by another. The highest intermediate ground is 133 feet above tide water, but may be reduced ten feet by digging to that depth the length of a mile. Two ponds, known by the name of Weymouth and Cranberry, the largest and least elevated of which covers five hundred acres, and is 14 feet higher than the summit of the proposed canal, will supply the upper locks with water by feeders four miles long. Whether the quantity of water contained in those ponds, and estimated equal to a daily supply of 450,000 cubic feet, will be sufficient for a sloop navigation; and whether any other ponds or streams may be brought in aid, does not seem to be fully ascertained. After descending twenty feet towards Weymouth and seventy towards Taunton, an ample supply for the lower locks will be derived from other large ponds, the principal of which are known by the names of Braintree and Nippinitic.

The expense may, on a supposition that the route is partly through a rocky soil, be estimated as follows:

Digging 26 miles at 30,000 dollars a mile,	$780,000
Lockage 260 feet at 1,250 dollars a foot,	325,000
Feeders, purchase of land, &c.	145,000
	1,250,000

II. New-Jersey Canal.

A company was incorporated some years ago, by the Legislature of New-Jersey, for opening a canal between the Rariton and the Delaware. Acting under the erroneous opinion, that the navigation of small rivers might be improved, and used as a canal, the company intended to have united, by a cross cut of one mile, the Assampink, or Trenton Creek, with Stoney Brook, a branch of Millstone River, and to have descended Trenton Creek, to the Delaware, and Stoney Brook, and Millstone River to the Rariton. The capital which was inadequate, was not paid; but their survey of the intended route has shewn the practicability of a canal for sea vessels, on a proper plan.

The distance from Brunswick to Trenton, is twenty-six miles; and the only obstacle in the way, is the "Sand Hills," some distance west of Brunswick; these may it is said be avoided by a deviation, which would not increase the distance more than two miles; and they may at all events be perforated, as has been done by the Turnpike Company, who have opened a road on a straight line between the two towns without having in any place an angle of ascent, of more than three degrees.

The highest intermediate ground between Assampink, and Stoney Brook, is only fifty feet above tide water; and it is suggested, that the summit level may be taken seven feet lower, cutting seven miles through a level meadow, between the confluence of the Assampink, and Shippetankin Creeks, and Rowley's Mill, near the confluence of Stoney Brook, and Millstone River.

An adequate supply of water will be drawn by short feeders from Philipp's Springs, Trenton Creek, Stoney Brook, and Millstone River, all of which are more elevated, than the route of the canal, the "Sand Hills," excepted.

The depth of water at the two extremities of the canal taken at low water, are feet at Brunswick, and ten feet at Lamberton, one mile below Trenton.

The expenses may be estimated as followeth :

Digging 28 miles, at 20,000 dollars per mile,	560,000 00
Lockage 100 feet, (probably less,) at 1,250 dollars per foot,	125,000 00
Feeders, purchase of land, and water rights,	115,000 00
	$ 800,000 00

III. Delaware, and Chesapeake Canal.

A company incorporated by the States of Delaware and Maryland, for opening this canal, has commenced its operations, now suspended for want of funds.

The canal will commence at Welsh Point on Elk River, an arm of the Chesapeake, and terminate at a distance of twenty-two miles on Christiana Creek, a branch of the Delaware. At low water, the depth of water in Christiana, is nine feet, and in Elk, twelve feet, within one hundred feet from the shore ; the tide rises four feet in both rivers. The canal might, without increasing the distance, be conducted to New-Castle, on the Delaware itself, instead of ending at Christiana Creek.

The highest intermediate ground, over which the canal will be carried on a level of thirteen miles in length, is seventy-four feet above tide water ; the descent being effected by nine locks on each side. The digging is generally easy ; no expensive aqueducts or bridges, nor any other obstacles, but those which have already been overcome, in digging the feeder through a very rocky soil.

The supply of water drawn from Elk River, by a feeder six miles in length, already completed, which is itself a boat canal, three and a half feet deep, united by a lock of ten feet lift with the main canal, is calculated to fill daily one hundred and forty-four locks ; a quanti-

ty sufficient on an average, for the daily passage of twenty-four vessels. A reservoir covering thirty, and which may be increased to one hundred and fifty acres, will supply occasional deficiencies; other reservoirs may be added, and Christiana, and White Clay Creeks, may hereafter be brought in aid of Elk River, if the supply should prove too scanty for an increased navigation.

The canal twenty-six feet wide at the bottom, and fifty at the top on the water line, being dug at the depth of eight feet, is intended for vessels of forty to seventy tons, drawing seven and a half feet water; but the banks twenty feet wide for towing paths, and one of which may be converted into a turnpike road, being raised three feet above the level of the water, will, by increasing the height of the lock gates one foot, admit a depth of nine feet of water in the canal, at which depth it would perhaps be eligible to dig at once. The locks eighty feet long, eighteen feet wide, and eight or nine feet deep, over the gate-sills, containing each 11.500 to 13.000 cubic feet of water, and with a lift of eight to nine feet each, will be constructed of hewn stone, laid in tarras. Those dimensions, both of the canal and locks recommended by Mr. Latrobe, the engineer of the canal, may be adopted in all the other canals for sea vessels, on this line of communication.

The present annual carriage across the peninsula, which would be drawn through the canal, is estimated at forty-two thousand tons, exclusively of passengers. This will be greatly increased by the facility which the canal itself will afford to the commercial intercourse between the two bays, and to the conveyance of articles now carried through other channels, or too heavy for transportation, at the expense of carriage. The coals wanted for Philadelphia, and which brought down from the sources of the Susquehannah, and Potomack, but principally from the vicinity of Richmond, would naturally pass through the canal, have been alone estimated at more than one hundred thousand tons a year. The annual carriage of all articles may, in the present

state of population be fairly estimated at one hundred and fifty thousand tons, and the direct annual saving to the community, at 300,000 dollars, being at the rate of two dollars a ton, for the difference between land and water carriage, across the peninsula, after paying the tolls. These, at the rate of fifty cents a ton, will give to the undertakers a revenue of 75,000 dollars; leaving, after a deduction of 10,000 dollars for annual repairs, and of 10,000 dollars more for attendance and contingencies, a nett income of 55,000 dollars.

The expenses of the whole work, are estimated as followeth:

Digging 22 miles, at 20,000 dollars a mile,	$ 444,000 00
18 locks, at 10,000 dollars each,	180,000 00
(The whole lockage being 148 feet, would at 1,250 dollars a foot, amount to 185,000 dollars.)	
Feeder, (nearly completed,) reservoirs, lock at the feeder, purchase of water rights, and land, including a debt of dollars due by the company,	226,000 00
	$ 850,000 00

The interest on which sum, at six per cent. is 51,000 dollars.

The capital originally subscribed, amounted to four hundred thousand dollars, divided into two thousand shares, of two hundred dollars each. One half of these have been forfeited, after a small payment of five dollars on each share. One hundred thousand dollars paid by the other stockholders, have been expended in preparatory measures, in the purchase of water rights, and in digging the feeder, which was considered as the most difficult part of the work. Seven hundred and fifty thousand dollars are still wanted to complete the work; of which sum, one hundred thousand dollars is payable by the stockholders, and the deficiency of six hundred

and fifty thousand dollars, must be drawn from other sources.

IV. *Chesapeake and Albermarle.*

1. The shortest communication between the Chesapeake and Albermarle sound is from North Landing, at the head of the tide of North-West River, which empties into Currituck Inlet, the easternmost arm of Albermarle, to either Kempsville or Great Bridge, at the head of the tide of two different branches of the south branch of Elizabeth River, which, passing by Norfolk, unites at Hampton Roads, with James River and the Chesapeake. The distance is stated at seven miles, and the levels said to be favorable. It is believed that the principal reason why this communication has not been attempted, is a bar in Currituck Inlet, which does not admit the passage of vessels drawing five feet water.

2. A company incorporated by the states of Virginia and North-Carolina, for opening a canal through the Dismal Swamp, has made considerable progress in the work.

The canal extends 22 miles in length from Deep Creek, a branch of the south branch of Elizabeth River, 7 miles above Norfolk, to Joyce's Creek, a branch of Pasquotank River, a northern arm of Albermarle sound. Vessels drawing 8 to 9 feet water may ascend both creeks to each extremity of the canal.

The intervening ground along the eastern margin of the Dismal Swamp is almost level, the rise towards the middle not exceeding two feet above the two extremities, which are only 18 feet and 9 inches above tide water. The digging is very easy; the only obstacles arise from the stumps and roots of trees, and are nearly overcome; and a single aqueduct, or rather culvert, over a small run emptying into the North-West River is necessary.

The swamp itself supplies, at the depth at which the canal is cut, the water which has heretofore been want-

ed ; and a sufficient supply may be drawn by a feeder of 3 miles and a half in length, cut through a perfect level, from Lake Drummond, a natural reservoir in the centre of the swamp, of fifteen miles in circumference, and about six feet higher than the water in the canal.

The canal, as cut by the company, is 24 feet wide, and 6 feet deep, with one bank on the west side for a towing path, 18 feet broad. The whole digging, with the exception of 2 miles, which must be deepened 3 feet, and of 3 quarters of a mile in another place not entirely finished, has been completed. The locks at the two extremities of the canal are not built ; but two have been erected at some distance from each extremity, probably in order to save some digging in the intervening space : they are made of square juniper logs, and have cost only three hundred dollars each.

The expense of digging has not exceeded 4,000 dollars a mile ; the whole capital expended amounts to one hundred thousand dollars, of which the state of Virginia has furnished 17,500 ; and it is stated that the whole work may be completed in one year, and will not, including the locks and the payment of some debts contracted by the company, exceed 25,000 dollars. But the canal, which, by the original act of incorporation, was to be 32 feet wide and 8 feet deep, can, on its present plan, be considered only as a local object, the principal utility of which consists in bringing to market the otherwise useless lumber of the swamp. The only boats which navigate it are flats, forty feet long, six feet wide, drawing two feet of water, and carrying eight thousand shingles.

It must, in order to become a national object, be capable of receiving the vessels which navigate Albermarle sound, and for that purpose be restored to its first intended dimensions, or rather be widened and deepened, on the plan adopted for the Chesapeake and Delaware canal. The expense would be as followeth :

Digging, deepening to 3 feet, preserving the same level the whole way, and widening to a proper breadth,

22 miles, at 8,000 dollars a mile,	$ 176,00
4 Stone locks at $ 10,000,	40,00
Feeder to Lake Drummond, aqueduct and contingencies,	34,000
	$ 250,000

3. The last mentioned canal is in the most direct line of the communication through Albermarle to Pamtico sound, and the adjacent southern sounds. It has been objected, that the navigation of Pasquotank River was intricate, and that it would be more advantageous to open a communication with Chowan River, which passing by Edenton, and then uniting with the Roanoke, forms Albermarle Sound.

A company was incorporated for that purpose; but the capital was not filled, and no other operation performed, but surveying the ground. The intended canal on that route, would commence at Suffolk, on Nansemond River, which empties into James River a few miles above and west of the mouth of Elizabeth River, and passing along the western margin of the Dismal Swamp, would reach, at a computed distance of 30 miles, Gates' court-house, on Bennet's Creek, a branch of Chowan River, which vessels drawing ten feet of water may ascend to that spot.

The highest intermediate ground is 28 feet above tide water, and consequently higher than the surface of lake Drummond. But Bennet's Creek, and Currípeake Swamp, were considered as affording a sufficient supply of water. Should this prove adequate, the principal objection to this route will be, that the canal lands at Suffolk instead of Norfolk. This consideration and the capital already expended on the canal from Elizabeth River to Pasquotank, seem to give a preference to this course.—To which may be added, that if it be preferable to strike the waters of Chowan River, a lateral canal may be hereafter opened, along the southern margin of the Dismal Swamp, from the southern extremity of the Elizabeth and Pasquotank canal, to Bennet's

Creek or Edenton. Whatever route may, after a critical examination of the ground, be thought the most eligible, the opening of this communication will be more easy and less expensive, than either of the three northern canals.

The following table is a recapitulation of the distance to be cut on the whole line, and of the estimated expense :

CANALS.	DIRECTION.	Distance. Miles.	Lockage. Feet.	Expense. Dollars.
Massachusetts,	Weymouth to Taunton,	26	260	1250000
New-Jersey,	Brunswick to Taunton,	28	100	800,000
Delaware and Chesapeake,	Christiana to Elk,	22	148	750,000
Chesapeake and Albermarle,	Eliz.Riv. to Pasquotank	22	40	250,000
	Total,	98	548	3050000

COMMUNICATIONS BETWEEN THE ATLANTIC AND WESTERN WATERS.

The Apalachian Mountains, to use an ancient generic denomination, extend in a direction west of south from the 42d to 34th degree of north latitude, approaching the sea, and even washed by the tide in the state of New-York, and thence, in their southerly course, gradually receding from the sea shore. Viewed as a whole, their breadth may be estimated at 110 miles; they consist of a succession of parallel ridges, following nearly the direction of the sea coast, irregularly intersected by rivers and divided by narrow valleys. The ridge which divides the Atlantic rivers from the western waters, generally known by the name of Alleghany, preserves throughout a nearly equal distance of 250 miles from

the Atlantic Ocean, and a nearly uniform elevation of 3,000 feet above the level of the sea.

Those mountains may however, be perhaps considered as consisting of two principal chains. Between these lies the fertile lime-stone valley, which, although occasionally interrupted by transversal ridges, and in one place by the dividing, or Allegheny ridge, may be traced from Newburgh and Esopus on the Hudson River to Knoxville on the Tennessee.

The eastern and narrowest chain is the Blue Ridge of Virginia, which, in its northeast course, traverses, under various names, the states of Maryland, Pennsylvania, and New-Jersey, forms the High Lands broken at West-Point by the tide of the Hudson, and then uniting with the Green Mountains, assumes a northerly direction and divides the waters of the Hudson and of Lake Champlain from those of Connecticut River. On the borders of Virginia and North-Carolina the Blue Ridge is united by an inferior mountain with the great western chain, and thence to its southern extremity, becomes the principal or dividing mountain, discharging eastwardly, the rivers Roanoke, Pedee, Santee, and Savannah, into the Atlantic Ocean; southwardly, the Chatahouchee and the Alabania into the Gulf of Mexico; and, westwardly, the New River and the Tennessee.—The New River, taking a Northwardly course, breaks through all the ridges of the great western chain, and, at a short distance beyond it unites, under the name of Kanhawa, with the Ohio. The Tennessee pursues at first a southwest direction between the two chains until having reached, and, in a westwardly course, turned the southern extremity of the great western chain, it assumes a northwardly direction and joins its waters with those of the Ohio, a few miles above the confluence of that river with the Mississippi.

The western chain, much broader, and generally more elevated, is known under the name of Cumberland and Gauley Mountains, from its southern extremity, near the great bend of the Tennessee River, until it becomes, in Virginia, the principal or dividing moun-

tain. Thence, in its northerly course, towards the State of New-York, it discharges westwardly the Green Briar River, which, by its junction with the New River, forms the Kanhawa, and the river Monongahela and Alleghany, which, from their confluence at Pittsburgh assume the name of Ohio. Eastwardly, it pours into the Atlantic Ocean, James River, the Potomack, and the Susquehannah. From the northermost and less elevated spurs of the chain, the Gennessee flows into Lake Ontario; and in that quarter the northerly branches of the Susquehannah seem to take their source from amongst the interior ridges, and, in their course to the Chesapeake, to break through all the mountains. From the Susquehannah, the principal chain assumes a more eastwardly direction, and, washed on the north by the lateral valley of the river Mohawk, whilst it gives rise, southwardly, to the Delaware, it terminates, under the name of Catskill Mountain, in view of the tide water of the Hudson.

This description has been introduced for the double purpose of pointing out all the rivers which can afford the means of communication, and of showing the impracticability in the present state of science of effecting a canal navigation across the mountains.

The most elevated lock canal, of which a correct description has been given, is that of Languedoc; and the highest ground over which it is carried, is only six hundred feet above the sea. It is not believed that any canal has been undertaken, or at least completed, in England, of an elevation exceeding 430 feet above the waters united by it. The Alleghany mountain is generally, and from observations made in several places, about 3000 feet above the level of the sea. The precise height of the dividing ridge was ascertained by the commissioners who laid out the United States road from Cumberland on the Potomack to Brownsville on the Monongahela, at 2,260 feet above the first, and at 2,150 feet above the last river. Cumberland, from the levels taken by the Potomack company, is itself 735 feet above tide water. Although some more advan-

tageous and less elevated places may be found, particularly amongst the ridges which divide some of the upper branches of the Susquehannah from the corresponding streams emptying into the river Alleghany; there is none which is not of an elevation much beyond what has ever been overcome by canals in any other country. The impracticability arises from the principle of lock navigation, which, in order to effect the ascent, requires a greater supply of water in proportion to the height to be ascended, whilst the supply of water becomes less in the same proportion. Nor does the chain of mountains through the whole extent, where it divides the Atlantic from the western rivers, afford a single pond, lake, or natural reservoir. It may be added, as a general feature of American geography that, except in the swamps along the southern sea coast, no lake is to be found in the United States south of 41 ° north latitude; and that almost every river north of 42 ° issues from a lake or pond.

The works necessary in order to facilitate the communications from the sea-ports across the mountains to the western waters, must therefore consist either of artificial roads extending the whole way from tide water, to the nearest and most convenient navigable western waters; or of improvements in the navigation of the leading Atlantic rivers, to the highest practicable points, connected by artificial roads acros the mountains, with the nearest points from which a permanent navigation can be relied on, down the western rivers.

The principal considerations in selecting proper directions for those communications are, the distance from the navigable western waters, both to tide water, and to the nearest navigable Atlantic river; and the extent of navigation, either natural or susceptible of improvement, which may be afforded by the rivers. Distance alone is mentioned so far as relates to roads, because the mountains, however insuperable for canals, offer no important impediment to land communications. So far from being an unsurmountable barrier to commercial intercourse between the two great sections of

the Union, it is now ascertained that those mountains may, almost in every direction, be crossed by artificial roads, as permanent, as easy, and less expensive, than similar works in the lower country. For congress having, contrary to current opinion, directed that the road from Cumberland to Brownsville should be laid out so that its ascent should not in any place exceed an angle of five degrees with the horizon, no difficulty has been experienced in effecting the object without cutting through hills, and although the road thus laid out, be, in a distance of 72 miles, two or three miles shorter than that heretofore in use.

Although the distance from the sea to the principal dividing mountain, through its whole length, between the western sources of the Susquehannah and those of the Savannah, be nearly the same, yet the Atlantic bays, penetrating the coast at different depths and in different directions, the distances from the sea ports to the nearest western navigable waters, varies considerably. Taken in straight lines from each port to the nearest branch, beyond all the mountains, of each of the four great western rivers, they may be stated as follows :

	MILES.
From Philadelphia to the confluence of the Conemaugh and Loyalhannon, branches of the Alleghany, . . .	220
From the city of Washington to the confluence of the rivers Monongahela and Cheat,	150
From Richmond to Morris', on the Kanhawa, below all the falls of that river, . .	210
From Savannah or Charleston to any navigable branch of Tennessee, the distance exceeds	300

The distance from the same western points to the upper navigation of the corresponding Atlantic rivers cannot be stated with precision, as the upper points to which the navigation of those rivers may be improved is not yet ascertained. The shortest portage between the waters of the Potomack and those of the Monongahela, in their natural state, from West Port, on the Potomack, to Cheat River, below the falls, is about fifty

miles in a straight line. But in order to secure a tolerable navigation, particularly on the Potomack, the route from Cumberland to Brownsville, (Red Stone old fort.) has been preferred, and the distance, by the road lately laid out, is 72 miles. The portage between the north fork of the Juniata, a branch of the Susquehannah, and the corresponding waters of the river Alleghany, is somewhat shorter. That between Pattonborough, on James River, and the falls of the Kanhawa, exceeds one hundred miles.

The most prominent, though not, perhaps, the most insuperable obstacle in the navigation of the Atlantic rivers, consists in their lower falls, which are ascribed to a presumed continuous granite ridge, rising about 130 feet above tide water. That ridge, from New-York to James River inclusively, arrests the ascent of the tide, the falls of every river within that space being precisely at the head of the tide. Pursuing thence southwardly a direction nearly parallel to the mountains, it recedes from the sea, leaving in each southern river an extent of good navigation between the tide and the falls. Other falls of less magnitude are found at the gaps of the Blue Ridge, through which the rivers have forced their passage. Higher up, the rapidity of the northern rivers, which penetrate through the inferior ridges of the great western chain, increases as they approach the dividing, or Alleghany mountain ; and their sources being nearly at the same elevation, their rapidity increases in proportion to the shortness of their course. For that reason the navigation of the Susquehannah above the Blue Ridge is better than that of the Potomack, which affords, as has been stated, the shortest communication from tide water to the nearest western river. The levels of the last-mentioned river having been taken by the Potomack company, the general result is annexed, as giving a more correct idea of the navigation of the Atlantic rivers, than could be conveyed in any other manner.

	DISTANCE. Miles.	FALL Feet.	RATE OF FALL. Feet per mile.
From the mouth of Savage River, down to Cumberland,	31	445	14 1-2
Thence to the Blue Ridge,	130 1-2	490	4
Harper's Ferry, or Shenandoah Falls, ...	5 1-2	43	
Thence to Great Falls, . .	40	39	1
Great and Little Falls, to tide water, ...	12	143	
Total,	219	1,160	

The papers marked (C.) contain the information which has been collected respecting the works executed or contemplated on the great rivers already enumerated. It has not been understood that any improvements of importance have been yet attempted on the Savannah and Pedee, nor on any of the tributary streams of the Ohio; and the communications received under this head relate only to the Santee, Roanoke, James River, Potomack, Susquehannah, and Ohio.

I. *Santee.*

The Santee, or Catawba, is said to be occasionally navigable for near 300 miles, as high up as Morgantown, in North-Carolina. Two companies have been incorporated by that State, and that of South-Carolina, for the purpose of improving its navigation. The lower falls are above Camden, and not far from the arsenal of the United States at Mount Rock. A canal had been commenced there, but either from want of success in the commencement, or from want of funds, the work appears to be suspended. The market for the produce brought down that river is Charleston; and the river

boats were obliged at the mouth of the river to enter the sea, and to reach that port by a navigation along the sea shore, for which they were not calculated. To remedy that inconvenience, and to insure a permanent navigation, a canal has been opened by another company, uniting the Santee with Cooper River, which empties into the harbour of Charleston.

The distance between the points united is 22 miles: the highest intervening ground was 52 feet above Santee, and 85 feet above the river Cooper; but it has been reduced 17 feet by digging; the descent to Santee being 35 feet, effected by four locks, and that to Cooper 68 feet, effected by nine locks.

The principal supply of water is afforded by springs arising from the marshy ground at the bottom of the canal, and by several drains which collect and bring from an adjacent swamp the sources of the river Cooper. The quantity is said to be seldom deficient; yet a steam engine has been contemplated, as perhaps necessary in order to raise from the Santee an adequate supply.

The canal was carried over some small streams by means of aqueducts; inconsiderable ravines have been filled, and the ground was dug in some places to the depth of sixteen feet, in order to preserve the level. But it appears that the roots of trees were the greatest obstacle encountered in digging the canal. Its breadth is 20 feet at the bottom and 35 feet at top; the depth of water is 4 feet, and it admits boats of 20 tons. The locks, made of brick faced with marble, are 60 feet long and 10 feet wide.

The capital expended is stated at 650,667 dollars, including sixty negroes and some tracts of land belonging to the company. The canal has been completed six years; the annual tolls had never exceeded 13,000 dollars before the year 1807, and the annual expenses are stated at 7,000 dollars. The want of success in this undertaking which, though completed, is very unprofitable, may be ascribed to several causes. The expense, compared with the work, is much great-

er than might have been expected, and probably than was necessary. The locks are too small for large boats, which are therefore obliged to pursue the former route down the Santee, and by sea to Charleston; and want of water is alleged as a sufficient reason for the size of the locks. But a canal in that situation cannot, in America, be profitable, unless the navigation of the main river with which it communicates is rendered safe and permanent; and whenever that of the Santee itself shall have been improved, the utility and profits of the canal will be considerably increased.

II. The lower or great falls of Roanoke, consist in a succession of rapids, which, in a distance of 15 miles, have a fall of 93 feet. This obstruction is such, that almost all the tobacco of that river is transported by land to Petersburgh, on the Appomatox branch of James River. A canal has been contemplated from the upper end of the falls to Murfreesborough, situated on the tide water of a branch of Chowan River, 25 miles above the mouth of Bennet's Creek, which has been before mentioned as one of the lines of communication between Albermarle Sound and the Chesapeake. The level is said to be favourable without any obstructions or valleys in the way. The distance is 38 miles, and the expense of a small canal for boats drawing two feet and a half of water, may be estimated as followeth:

Digging 38 miles, at $ 6000 a mile,	$ 228,000
Lockage, 93 feet, at $ 800 a foot,	74,400
Feeder, land, &c.	47,600
	350.000

The capital for this canal has never been subscribed, and it has been suggested that it would be practicable to open one to Petersburgh. It is not believed that any hills intervene in that course; and the greatest obstacle will be found in crossing the branches of Chowan River.

III. *James River.*

A company, incorporated by the State of Virginia, for the improvement of the navigation of the river generally, has removed some obstructions in the upper part of the river, and is bound by the charter to render it so far navigable that there may never be less than 12 inches of water over any of the shoals or rapids, from the upper end of the Lower or Great Falls to Pattonborough, a distance of 220 miles. The natural navigation of the river through that extent, is considered as better than that of any other Atlantic river above the falls.

A communication has been opened by the company, from Westham, at the upper end of the Great Falls, to Shockoe Hill, in the city of Richmond, in the following manner. The water is drawn at Westham from the river into a canal 200 yards in length, at the end of which boats, descending 34 feet through three locks, re-enter the river; and after using its natural navigation three miles, are brought by a canal three miles and a half in length to a basin on Shockoe Hill, where the navigation terminates.

That basin is about 80 feet above tide water, and one mile and a half from Rockets, the port of Richmond. The whole fall from the upper end of the canal at Westham to the basin, may be stated at 48 feet, and the distance at six miles and a half. The canal is 25 feet wide, and admits boats of eight tons, drawing three feet of water. The locks, 80 feet long and 16 feet wide, are of solid masonry, but the cement is defective. Three aqueducts have been thrown across valleys intervening in the course of the canal; and some difficult digging was necessary on the side of hills and through ledges of rocks.

The canal, according to the charter, was intended to have been brought down to tide water. The performance of that condition is now suspended by an act of the legislature of Virginia, and there seems to be a considerable diversity of opinion on that subject. In a

national point of view, the plan which will at the least expense put coals on board vessels lying at Rockets, deserves the preference. For coal is in no other part of the United States found in abundance in the vicinity of tide water. At present the expense of transportation by the canal is already reduced to one third of the land carriage.

The original capital of the company amounted to 140,000 dollars, of which the State of Virginia owns fifty thousand; and ninety-one thousand dollars arising from the proceeds of tolls had, before the first of January, 1805, been applied to the work, making, together, an expenditure of 231,000 dollars. The annual tolls, raised on fourteen thousand tons of country produce, and on two thousand coal boats, have amounted to 16,750 dollars; and the annual repairs and expenses are estimated at 5,000 dollars. But as the company draw also a revenue from the rent of water, applied to mills and other water works erected along the canal, they have been able in some years to make dividends of 16,800 dollars, being at the rate of twelve per cent. on the original capital; but of only about seven per cent. if calculated on the the sum of 244,000 dollars, the amount of capital expended, and interest accrued before any dividend was made.

IV. *Potomack.*

The company incorported by the States of Maryland and Virginia, for improving the navigation of that river, has executed the following works:

1. At a distance of twelve miles above the head of the tide, which ascends about three miles above the city of Washington, the river is 143 feet higher than tide water. At that place, designated by the name of *Great Falls*, the boats, passing through a canal one mile in length, six feet deep and twenty five feet wide, descend seventy-six feet by five locks one hundred feet long and twelve feet wide, each, and, re-entering the river, follow

its natural bed eight miles and a half. Another canal of the same dimensions, and two miles and a half in length, brings them then through three locks, and, by a descent of thirty-seven feet, to tide water. This last is distinguished by the name of *Little Falls*. The two lower locks of the Great Falls, excavated out of the solid rock, have each a lift of eighteen feet ; the three upper locks of solid masonry are of unequal height, and have, together, a lift of forty feet. The three locks of the Little Falls are each one hundred feet in length and eighteen feet wide. That breadth is unnecessary and consumes too much water, a defect which will be remedied when stone locks will be substituted to those now in use, which being of wood, will soon be decayed.

Three other canals, without locks, have been opened around three distinct falls ; the principal, at the Shenandoah Falls, below Harper's Ferry, and at the place where the Potomack breaks through the Blue Ridge is one mile in length around a fall of fifteen feet. Between this and the Great Falls, another canal, three fourths of a mile in length, is opened around the Seneca Falls. The third, fifty yards in length, has been cut around Houre's Falls, five miles above the Shenandoah Falls. Above this place the navigation has been improved by deepening occasionally the channel, raising the water in shallow places by small dams, and opening sluices along the shore. It is believed that by multiplying the number of those low dams, by throwing the channel along the shore, and, when necessary, opening canals with or without locks around the principal rapids, the navigation may be improved, perhaps, as high up as Cumberland, 188 miles above tide water, to such a degree as to render the river passable for boats, the greater part of the year. And if this be found practicable on the Potomack, which is the most rapid of the great Atlantic rivers, the same improvements may, with greater facility, be effected on any of the others. It will be indispensable, in order to attain that object on the Potomack, that additional canals, with locks, should be opened at the Shenandoah, or Blue Ridge Falls, which,

as has already been stated, fall 43 feet in the distance of five miles.

2. The Shenandoah, a river nearly as large as the Potomack itself, after a course of 250 miles through the great Limestone Valley, unites its waters with those of the Potomack, at Harper's Ferry, just above the Blue Ridge. From Port Republic, till within eight miles of the Potomack, a distance of near 200 miles, it affords a good navigation, the fall of the river being at the rate of less than two feet a mile. In the last eight miles, it falls eighty feet, and was impassable before the improvements completed last year by the Potomack Company. Six different canals 20 feet wide, four feet and a half deep, and extending altogether, 2,400 yards, have been opened around the most difficult falls. Through those, and five stone locks, 100 feet long, and twelve feet wide each, and effecting together, a descent of near fifty feet, the communication is now opened, and will render the undertaking much more productive than heretofore.—The water in all those canals and locks, as well as in those executed on the Potomack, is uniformly supplied by the river itself.

The capital originally subscribed, amounted to 311, 560 dollars, divided into 701 shares; of which the state of Maryland owns 220, and the state of Virginia, 70.—The total amount expended, including an additional payment received from late subscribers, 38,000 dollars, arising from tolls, which have been applied to the work, and a debt of about 67,000 dollars contracted by the company, amounts to 444,652 dollars. The annual tolls raised on eight thousand tons of sundry articles, valued at more than half a million of dollars, have not, before the opening of the Shenandoah, exceeded 15,000 dollars; and the annual expenses and repairs are stated at 5,000 dollars.

One hundred shares of one hundred and forty-five pounds sterling each, remain open for subscription.

V. *Susquehannah.*

This river has no perpendicular, or altogether impassable falls; but from the head of the tide, up to the Pennsylvania line, a distance of ten miles, the navigation is impeded by a succession of dangerous rapids; and these, though occasionally separated by sheets of smooth water, continue 40 miles higher up, at least as far as Columbia; the whole fall from this place to the head of the tide being estimated at about 140 feet. The navigation through that distance, at all times dangerous, is practicable only during the high freshets, when rafts and flat bottomed boats 80 feet long, and 17 feet wide, may descend, from the several widely extended upper branches of the river. Less dangerous falls are found at the place where it breaks through the Blue Ridge; above which, the natural navigation from Middletown upwards, whether up the Juniata, the West-Branch, or the East-Branch, is much better than that of the Potomack, and has been improved in several places at the expense of the State of Pennsylvania. A canal one mile long, and four feet deep, with two brick locks, has also been opened around the Conewago Falls, in the gap of the Blue Ridge; fourteen thousand dollars having been paid for that object, by the same state. Its entrance is difficult, and it is used for water works, being free for navigation, though private property. From Columbia, down to the Maryland line, considerable improvements in the bed of the river have also been made, at the expense of the two States, and the descending navigation has, on the whole, been improved; but few boats ever attempt to ascend. Nor is it believed that the natural advantages of the most considerable Atlantic river, will ever be fully enjoyed until a canal shall have been opened the whole way from Columbia, either to tide-water, or to the Delaware and Chesapeake canal.

A company, incorporated by the state of Maryland, for opening a canal around the falls, in that part of the river which extends from the Pennsylvania line to tide

water, has completed that part of the work, the utility of which is but very partially felt, whilst the bed of the river remains the only communication from its upper extremity up to Columbia.

The canal, 30 feet wide, three feet deep, and admitting boats of 20 tons, is nine miles in length, with a fall of 59 feet. The descent is effected by eight stone locks, each of which is 100 feet in length, and twelve feet wide. The water is supplied by the river itself; and in order to cross the rivers, Conawingo, and Octorara, these, by means of dams, have been raised ten and twelve feet to the level of the canal.

Its defects consist in the want of sufficient breadth of the locks, which do not admit the rafts, and wide flat bottomed boats, generally used in bringing down the country produce, and in want of water at the lower end of the canal. This last defect may be remedied, by extending the canal 700 yards lower down, along the edge of the river; and it is probable, that as timber will become more scarce and valuable in the upper branches of the Susquehannah, boats of a different construction will be used. In the mean while the annual tolls have not yet amounted to one thousand, whilst the annual expenses are stated at twelve hundred dollars, and the capital expended at 250,000 dollars.

The attempts made to open a communication from Middletown, in the Limestone Valley, to Philadelphia, partly by canals, and partly by means of the Schuylkill, will be noticed under the head of "Interior Canals."

VI. *Ohio.*

The navigation of the Kanhawa, and of the eastern branches of the Tennessee, Monongahela, and Alleghany, in their course through the mountains, may at a future period be improved. But from the foot of the mountains, all those rivers, and particularly the Ohio, flow with a much gentler current than the Atlantic rivers: a circumstance easily accounted for, when it is

recollected that Brownsville, on the Monongahela, and at a distance of two thousand miles, by water, from the sea, is only 115 feet more elevated than Cumberland, on the Potomack; whilst this river, with all its meanders, reaches tide water within less than two hundred miles. All those rivers, at the annual melting of the snows, rise to the height of more than forty feet, affording, from the upper points to which they are navigable, a safe navigation to the sea for any ship that can pass over the bar at the mouth of the Mississippi. As early as the year 1793, a schooner built on the Monongahela, between Brownsville and Pittsburgh, reached New-Orleans by that extraordinary inland navigation, and arrived safe at Philadelphia. This first essay stimulated the spirit of enterprise, so conspicuous in the American character; and numerous vessels, from one hundred to three hundred and fifty tons burthen, are now annually built at several ship yards on the Ohio, even as high up as Pittsburgh, and bringing down to New-Orleans the produce of the upper country consumed there, carry to Europe, and to the Atlantic ports of the United States, the cotton, the sugar, and the tobacco of Lousiana, and of the states of Tennessee and Kentucky.

That branch of national industry gives value to the immense forests of the Ohio and of its numerous branches, will soon make a considerable, and, perhaps, necessary accession to the shipping of the United States, and has a tendency to diminish the price of freights from New-Orleans to the other American, and to foreign ports. The importance of this last consideration will be duly felt, if the magnitude of the exports, of which New-Orleans is destined to be the emporium, be contrasted with the probable amount of its importations.—For such are the labour, time, and expense necessary to ascend the rapid stream of the Mississippi, and the nature of its banks, annually overflowed on a breadth of several miles, precludes the possibility of towing paths; that whilst the greater part of the produce of the immense country watered by that river and its tributary streams, must necessarily be exported through its chan-

nel, the importations of a considerable portion of that country will continue to be supplied from the Atlantic sea-ports, by water and land communications, susceptible of considerable improvement. And thus, unless another outlet be found for a portion of the exports, or unless the upper country can supply vessels, those exports must necessarily pay a double freight.

The only impediments to that navigation are on the Tennessee, "the Muscle Shoals," of which no particular account has been received, and, on the Ohio, the falls of Louisville. Ordinary boats can with difficulty pass these in summer, and the navigation is, even during the freshets, dangerous for the large vessels. The attention of the legislature of Kentucky, and of the inhabitants of the western country generally, has therefore been particularly drawn to the opening of a canal at that place. A company has been lately incorporated by the State of Kentucky for that purpose, with a capital which may amount to 500 000 dollars, but a small portion of which has yet been subscribed. The expense, however, is estimated at a sum less than the nominal capital.

The proposed canal would be near two miles in length, and must be dug, in some places, to a depth of 27, but generally of about 16 feet; the breadth at the bottom being 20 feet, with the necessary slope, would make it generally 68 feet wide at top, and in particular places not less than one hundred. The fall, at low water, is about 22 feet, and would require three locks, of dimensions sufficient to pass ships of 400 tons, and drawing 14 feet of water. The greatest expense will be that of digging and removing the earth, which may be estimated at 400,000 cubic yards, and according to the representation made of the nature of the ground, will not probably cost more than 200,000 dollars. To this may be added 100 000 dollars for the locks and other necessary works, making altogether three hundred thousand dollars. The greatest difficulty seems to be the protection of the locks and canals against the rise of the river, which sometimes overflows the whole ground through

opened

The expense of the improvements suggested in the communications between the Atlantic and western waters, may be stated as followeth:

1st. Four artificial roads from the four great western rivers, the Alleghany, Monongahela, Kanhawa, and Tennessee, to the nearest corresponding Atlantic rivers, the Susquehannah or Juniata, the Potomack, James River, and either the Santee, or Savannah, leaving to the several states the continuation of those roads eastwardly to the nearest sea-ports. Those roads should unite on each river, points from which a permanent and safe navigation downwards, could except during the driest seasons, be relied on, and will therefore on each route, be estimated at one hundred miles, making altogether 400 miles, which at 7000 dollars a mile, the materials being generally on the spot, would cost $ 2,800,000

2d. The improvement of the navigation of the four Atlantic rivers from tide water to the highest practicable point, effected principally by canals around the falls, wherever practicable, and by locks whenever necessary.—The most expensive of these would be the proposed canal from Columbia on the Susquehannah, either to tide water, or to the Delaware and Chesapeake canal. And considering how much has been effected already, and may still be done on the other rivers, by the several incorporated companies, it is believed that every useful improvement might be completed by a public expenditure not exceeding 1,500,000

3d. The canal at the falls of Ohio, estimated at 300,000

Making altogether, $ 4,600,000

Although a canal navigation uniting the Atlantic and western waters, in a direct course across the mountains,

appears impracticable, yet those mountains may be turned either on the north, by means of the Mohawk valley and of Lake Ontario, or on the south, through Georgia and the Mississippi Territory. The first communication will be noticed under the head of "the river St. Lawrence and great Lakes." Of the second, it will be sufficient to observe, that the country lying between the sources of the rivers Chatahouchee and Mobile, and the gulf of Mexico, is an inclined plane, regularly descending towards the sea, and that by following the proper levels, it presents no natural obstacle to the opening of a canal, fed by the waters of the two last-mentioned rivers, and extending from the tide water on the coast of Georgia, to the Mississippi. The distance in a direct line is about 550 miles, and to be overcome, requires only time, perseverance, and labour. When it is recollected that such an undertaking would discharge the Mississippi into the Atlantic, the remarks already made on the trade of that river, and other obvious considerations, will sufficiently point out its immense importance. Nor should the plan, on account of its magnitude, be thought chimerical, for the elevation and other natural obstacles of intervening ground, or want of a sufficient supply of water, and not distance, are the only insuperable impediments to an artificial navigation.

This work, which is presented not as an immediate, but as a distant object, worthy of consideration, would probably require ten millions of dollars and thirty years for its completion. The annual sales of the public lands in the Mississippi Territory, which are estimated at fifty millions of acres, would, after paying the debt due to the State of Georgia, afford sufficient funds; and the increased value of the residue, would alone more than compensate the expense.

It is proper to add, that an inland navigation, even for open boats, already exists from New-Orleans by the canal Carondelet, to the lake Pontchartrain, thence between the coast and the adjacent islands to the bay of Mobile, and up its two principal rivers, the Alibama and

the Tombigbee, to the head of the tide, within the acknowledged boundaries of the United States. The current of these two rivers being much less rapid than that of the Mississippi, they have long been contemplated, particularly the Tombigbee, as affording a better communication to the ascending or returning trade from New-Orleans to the waters of the Tennessee, from which they are separated by short portages.

COMMUNICATIONS BETWEEN THE ATLANTIC RIVERS & THE RIVER ST. LAWRENCE AND GREAT LAKES.

Vessels ascend the river St. Lawrence from the sea to Montreal. The river Sorel discharges, at some distance below that town, the waters of Lake George and Lake Champlain, which penetrate southwardly within the United States. From Montreal to Lake Ontario, the ascent of the river St. Lawrence is estimated at about 200 feet. From the eastern extremity of Lake Ontario, an inland navigation for vessels of more than 100 tons burthen is continued more than one thousand miles, through Lakes Erie, St. Clair, and Huron, to the western and southern extremities of Lake Michigan, without any other interruption than that of the falls and rapids of Niagara, between Lake Erie and Lake Ontario. The descent from Fort Schlosser to Devil's Hole, a distance of four miles, which includes the perpendicular falls of Niagara, has, by correct measurement, been ascertained at 375 feet. The whole fall from Lake Erie to Lake Ontario is estimated at 450 feet, making the elevation of Lake Erie above tide water six hundred and fifty feet.

Lake Superior, the largest of those inland seas, communicates with the northern extremity of Lake Huron, by the river and rapids of St. Mary's. The fall of these is not ascertained: but it is said that a small canal has been opened around the most difficult part by the north-west fur company.

Five of the Atlantic rivers approach the waters of the St. Lawrence, viz. the Penobscot, Kennebeck,

Connecticut, the North, or Hudson River, and the Tioga branch of the Susquehannah. This last river will afford a useful communication with the river Seneca and Gennessee, which empty into Lake Ontario. The length of the portage has not been precisely stated; and the general navigation of the Susquehannah has already been noticed. It may, however, be observed, that it is the only Atlantic river whose sources approach both the western waters, and those of the St. Lawrence.

The three eastern rivers afford convenient communications with the province of Lower Canada, but not with that extensive inland navigation which penetrates through the United States, within two hundred miles of the Mississippi. No statement has been received of any improvement having yet been made on the Penobscot or Kennebeck; and a very imperfect account has been obtained of some short canals opened around the several falls of the river Connecticut. One at Bellows Falls, in the State of Vermont, has been particularly mentioned, and is the highest improvement on the river.

What is called the North River, is a narrow and long bay; which, in its northwardly course from the harbour of New-York, breaks through, or turns all the mountains, affording a tide navigation for vessels of 80 tons to Albany and Troy, 160 miles above New-York. This peculiarity distinguishes the North River from all the other bays and rivers of the United States. The tide in no other ascends higher than the granite ridge, or comes within thirty miles of the Blue Ridge, or eastern chain of mountains. In the North River it breaks through the Blue Ridge at West Point, and ascends above the eastern termination of the Catskill, or great western chain.

A few miles above Troy, and the head of the tide, the Hudson from the north, and the Mohawk from the west, unite their waters, and form the North River. The Hudson, in its course upwards, approaches the waters of Lake Champlain, and the Mohawk those of Lake Ontario.

I. *Hudson and Champlain, or Northern Navigation.*

A company was incorporated several years ago by the State of New-York, for the purpose of opening this communication, and a survey taken by Mr. Weston, a copy of which has not yet been obtained. From collateral information, it appears that it was proposed to open a canal 12 miles long, with a lockage of 106 feet, from Waterford, at the confluence of the Hudson and Mohawk, to the upper end of the great falls of Stillwater. This was considered as the most difficult part of the whole route, and the expense estimated at 275,000 dollars. Another canal and lock would be necessary around the falls of Fort Miller: but the remainder of the navigation up the Hudson to Fort Edward, does not require any material improvement.

At some distance above Fort Edward, it was intended to connect, by a canal and locks, the Hudson with the North Wood Creek, at Fort Ann. The navigation down the creek to Skeensborough is used, but requires to be improved. At this place, where falls render another canal necessary, North Wood Creek empties into the south bay of Lake Champlain; and thence is a natural sloop navigation through the whole extent of the lake. The expense of the works, from Fort Edward to Skeensborough, had been estimated at 200,000 dollars.

The funds of the company were insufficient, and have, it is said, been expended, without much permanent utility, at Stillwater and Skeensborough.

The distance in a straight line from Waterford to Skeensborough is fifty miles, and the expense of opening a permanent boat navigation, on a proper plan, through the whole line, is, from imperfect materials, estimated at about 800,000 dollars. This communication would divert to a port of the United States the trade of one half of the State of Vermont, and of a part of that of New-York, which is now principally carried through the channel of the St. Lawrence, and of the province of Canada.

II. *Mohawk and Ontario, or Western Navigation.*

A company, incorporated by the State of New-York, for the improvement of this navigation, has made considerable progress, and an accurate survey having been taken of the distances and levels of the greater part of the route, the result will, in the first place, be stated.

	DISTANCE. *Miles.*	FALLS. *Feet.*
From the tide water at Troy to Lansing Mills on the Mohawk, is found the greatest impediment to the navigation of that river, consisting of the Cohoes Falls, which are 70 feet perpendicular, and of a succession of other falls, which continue to the North River,	4 2-3	140
From Lansing Mills up the Mohawk to Schenectady, the height of the river, at the time when the survey was taken, prevented Mr. Weston from correctly ascertaining the levels. The fall for that distance is therefore estimated,	12 1-3	23 1-4
From Schenectady to the Little Falls, - - - -	57 1-2	110 1-2
The Little Falls which, before the improvements made by the company, interrupted altogether the navigation, - - -	3-4	42
From the Little Falls to Fort Stanwix, now Rome, - -	48	59 1-2

This is the head of the navigation, and the summit level between it and West Wood Creek, a branch of Lake Ontario, is nine feet and three fourths above that

	DISTANCE. *Miles.*	FALLS. *Feet.*
part of the river Mohawk where the navigation ceases, - -	1 3-4	9 3-4
	125	390

The whole course of the Mohawk is therefore 125 miles in length, and the fall through that distance from the summit level to tide water is 390 feet.

At the distance of one mile and three quarters is Wood Creek, the bed of which is used to its entrance into Lake Oneida, the distance along its meanders being twenty-three miles, but in the line in which a canal might be cut only fourteen miles, and the fall sixty feet, - - - - 14 60

The Oneida forms a natural canal of twenty miles in length, and 20
communicates, by the Onondaga and Oswego rivers, with Lake Ontario. The distance by water down those two rivers to Oswego, on Lake Ontario, is 63 miles.—The upper part of the navigation is generally good, but the last 12 miles from the Oswego Falls, which are not passable to Lake Ontario, are a continued rapid.—The fall from lake Oneida to lake Ontario has not been ascertained by actual measurement, but is estimated at 130 feet. From Rotterdam, on Lake Oneida, to the mouth of Salmon Creek, on Lake Ontario, a few miles east of Os-

	DISTANCE. *Miles.*	FALLS. *Feet.*
wego, the distance is twenty-two miles, and the ground being favorable, it is expected that the line of canal would not exceed twenty six miles,	26	130
	60	190

The elevation of the summit level between the Mohawk and the waters of Lake Ontario, being only three hundred and ninety feet above the tide water at Troy, and 190 feet above Lake Ontario, a canal navigation is practicable the whole distance. Whether this should be attempted for a sloop or boat navigation must depend principally, if not altogether, on the supply of water.—It is stated that the canal from the summit level to Troy must necessarily follow the valley of the Mohawk, and perhaps occasionally enter and cross the river.—Calculated for a boat navigation, the expense may be estimated as followeth:

Mr, Weston estimated the expense of a canal from Lansing mills to tide water at Troy, around the Cohoes Falls, at	$ 250,000
The distance from the summit level to Lansing Mills, is 120 miles, and to Lake Ontario, deducting the 20 miles occupied by Lake Oneida, 40 miles; together 160 miles of canal, the digging of which at 8,000 dollars a mile, is	1,280,000
The fall from the summit level to Lansing Mills is 250 feet, and to Lake Ontario 190 feet; together 440 feet lockage, which will require 55 locks of eight feet lift each. These at 7,500 dollars, the cost of the stone locks erected by the company at the Little Falls, will cost about	420,000

Feeder and aqueducts may be estimated at	250,000
Making altogether	$ 2,200,000

It is not believed that a sloop navigation, if practicable, could be effected for a less sum than five millions of dollars.

The following works have already been completed by the company :

At the Little Falls a canal three quarters of a mile in length, has been opened, and a descent of 42 feet effected by six locks of solid masonry, each of which is 70 feet long, and 12 feet wide.

At the German Flats, four miles above the Little Falls, another canal one mile in length, with two stone locks of the same materials and dimensions, effects a descent of ten feet.

On the summit level a canal one mile and three quarters in length, and supplied with water from the River Mohawk by a short feeder, unites that river and Wood Creek, by means of two locks of the same dimensions and materials, one at each extremity of the canal. All those canals are two feet and a half deep, twenty-four wide at bottom, and thirty-two at top, and admit boats of ten tons. It is proper to state, that at first, wooden locks had been erected at the Little Falls, and brick locks on the summit canal. At both places they had become totally unfit for service at the end of seven years, and it was necessary to replace them by stone locks ; a circumstance which increased considerably the undertaking.

Several minor improvements have been made on the Mohawk ; and the navigation of Wood Creek, of which the principal defect is want of water, has been improved by raising dams, and by the erection of four temporary wooden locks. But until a canal shall have been opened the whole distance from the summit level to Lake Oneida, the navigation will be imperfect, and the profits inconsiderable.

The funds of the company do not enable them to undertake the necessary improvements at the two extre-

mities of the line, a canal around the Cohoes Falls to tide water, and another canal from Lake Oneida to Lake Ontario. The usual portage at the first place is from Schenectady to Albany, and a very good and expensive artificial road of 16 miles, made by another company, unites the two towns. Another company has lately been incorporated for the purpose of making an artificial road at the other extremity of the line from Rotterdam, on Lake Oneida, to Salmon Creek, on Lake Ontario.

The capital of the company is 232,000 dollars, of which the State of New-York owns 92,000. But, with the exception of one dividend of 3 per cent. all the tolls have been applied to the works; and including these and a debt of 20,000 dollars due by the company, the whole expenditure amounts to 370,000 dollars. The annual tolls do not yet exceed 13,000 dollars.

III. *Niagara.*

The fall from Lake Erie to Lake Ontario has already been stated at 450 feet. A company had also been incorporated by the State of New-York for the purpose of opening a canal at this place; but it does not appear that any thing was attempted after the survey had been made. The intention seems to have been to open a canal navigation for boats only from Fort Schlosser to Devil's Hole, the Lake itself and Giles's Creek would have supplied the water, and the expense was estimated at 437,000 dollars.

It is, however, evident that the canal, in order to be as eminently useful as the nature of the undertaking seems to require, should be on such a scale as to admit vessels which can navigate both lakes. Considering the distance, which in that case must be extended to about ten miles, and the lockage of 450 feet, it is not believed that the expense can be estimated at less than 1,000,000 dollars.

The works necessary to effect water communications

between the tide water of the North River, the St. Lawrence, and all the lakes, (Lake Superior only excepted,) are therefore estimated at four millions of dollars :

Northern navigation to Lake Champlain,	$ 800,000
Western navigation to Lake Ontario,	2,200,000
Falls of Niagara for a sloop navigation,	1,000 000
	4,000,000

The papers relative to these communications will be found under the letter (B.) But their utility will not be confined to the extensive navigation of the lakes themselves. For the mountains being completely turned, when arrived into Lake Erie, the ridge which separates the waters emptying into that and into Lake Michigan, from the northern branches of the Ohio, and from the waters of the Mississippi, is of a moderate elevation, and is gradually depressed in its course westwardly. There is no doubt of the practicability of opening canals at a future period, between several of those waters, either by selecting proper levels, or by means of short tunnels across favourable parts of the ridge. It will at present be sufficient to point out the principal communications now in use.

The distance from lake Erie to lake Chetoughe, an extensive and important elevated reservoir, which is the source of the Canowaugo branch of the Alleghany, is seven miles, by a continual ascent, the elevation of which is not ascertained.

From Presque Isle, on Lake Erie, to Le Beuf, on French Creek, another branch of the Alleghany, the distance is sixteen miles, and a company is incorporated by the State of Pennsylvania, for making an artificial road across that portage.

The navigation from lake Chetouge, and from Le Beuf, to Pittsburgh, offers no impediment whenever the waters are high ; and the greater part of the salt now consumed in the north west counties of Pennsylvania, as far as Pittsburgh, and some distance down the Ohio, is brought from the salt springs of New-York,

by Oswego, through Lake Ontario; then across the portage of Niagara, to Lake Erie, and then by either of the two last mentioned portages, to the waters of the river Alleghany.

The distance from the place where the Cayuga, a river emptying into Lake Erie, ceases to be navigable, to the navigable waters of the Muskingum, which empties into the Ohio 170 miles below Pittsburgh, is only six miles; and a company is said to be formed for the improvement of that communication.

Sandusky River and the Scioto, take their sources in the same swamp. The navigation of the Miami of Lake Erie, is interrupted by some falls; but its upper branches approach those of the Miami of the Ohio, and of the Wabash, and are stated as being nearly on the same level.

The Illinois River, which empties into the Mississippi above St. Louis, rises in a swamp, which, when the waters are high, affords a natural canoe navigation to the sources of Chicago Creek, a short stream which falls into Lake Michigan, at its southern extremity.

Another communication generally used by the Indian traders, is that from Green Bay, also in Lake Michigan, to the Mississippi, by Fox River, and the Ouisconsing. Nor is there any doubt that if the inland navigation between the North River and the Lakes, was completely opened, the whole inland trade, either of the Mississippi, by Lake Michigan, or of the north west by Lake Superior, must necessarily centre in an Atlantic port of the United States. A consideration of minor importance, as a commercial object, when compared with the other advantages of that great communication, but of great weight in its relation to the political intercourse of the United States with the Indians.

INTERIOR CANALS.

Under this denomination, will be included all the canals of which any knowledge has been obtained, and

which are not immediately on the rivers opening communications with the western waters, or with those of the St. Lawrence, although some of them may be considered as extending those communications to more remote sea-ports. The documents from which the information is extracted, will be found under the letters (C c.)

I. *Merrimack.*

The navigation of that river which, rising in the State of New-Hampshire, falls into the sea, at Newburyport, after a course of 180 miles, is interrupted by several falls. A canal, called Blodget's canal, has been opened around Amoskeag Falls. Lower down, and about 40 miles from the sea, the Essex canal, 4 miles in length and admitting boats drawing three feet and a half, will open a communication around the Patucket Falls, effecting, through three locks, a descent of 34 feet. From the lower extremity of the canal, the river is navigable to the head of the tide, at Havenhill, although the fall be 45 feet within that distance. No particular account has been received of the capital expended; but it is believed that the work will be profitable to the undertakers.

The Middlesex canal, uniting the waters of that river with the harbour of Boston, is however the greatest work of the kind which has been completed in the United States.

That canal, 12 feet wide, and three and a half feet deep, draws its supply of water from Sudbury or Concord River, a branch of the Merrimack; and from the summit ground extends six miles with a descent of 28 feet to the Merrimack, above the Patucket Falls, and 22 miles with a descent of 107 feet to the tide water of the harbour of Boston. The descent to the Merrimack, is effected by three, and that to tide water, by nineteen locks. They are all 90 feet long, 12 feet wide, of solid masonry, and excellent workmanship.

In order to open that canal, it was necessary, to dig in some places at the depth of 20 feet, to cut through ledges of rocks, to fill some valleys, and morasses, and to throw several aqueducts across the intervening rivers. One of these across the river Shawshine, is 280 feet long, and 22 feet above the river. All those obstacles have been overcome, and boats of 24 tons, 75 feet long, and 11 feet wide can navigate the canal. Those in most general use, are of smaller dimensions, and are drawn by two horses, at the rate of three miles an hour. A raft of one mile in length, and containing eight hundred tons of timber, has been drawn by two oxen, part of the way, at the rate of one mile in an hour. Common boats pass from one end of the canal, to the other in 12 hours. The capital expended on the work, is stated at 478,000 dollars, and the water rights, and necessary land cost a further sum of 58,000 dollars. The total expense has exceeded 550,000 dollars; the tolls have never yet exceeded 17,000 dollars a year, but are increasing.

Several other canals have been contemplated in the State of Massachusetts, intended to unite the waters of Providence, or Patucket River, with those of Charles River, which falls into the harbour of Boston, and of the river Connecticut. The grounds have been surveyed, but no particular description has been obtained, and the works have not yet been commenced.

II. *Schuylkill and Delaware.*

A company was incorporated several years ago, by the State of Pennsylvania, for opening a canal from Norristown, on the river Schuylkill, to the tide water of the Delaware at Philadelphia. The distance is 16 miles. the fall 53 feet. and the canal deriving its waters from the Schuylkill, would have been carried on a level to Philadelphia, and in its descent to the Delaware, supplied the city with water, and the shipping with docks. The expense had been estimated at 533,000 dollars; the work was commenced, one third part of

the digging effected, and a considerable sum expended. But either from want of funds, or from an improper selection of the ground, or from other causes not fully understood, the undertaking, if not altogether abandoned, has been suspended for several years.

This canal was intended as the first link of an extensive western communication. The Schuylkill from Norristown, to Reading, 46 miles higher up the river, being navigable a great portion of the year, was considered as the next link.

III. *Schuylkill and Susquehannah.*

Another company was incorporated for the purpose of opening an inland navigation, between Reading on the Schuylkill, to Middletown, on the Susquehannah. Both towns are in the great Limestone Valley, beyond the Blue Ridge, and the distance is 70 miles. It had been at first supposed, that it would be sufficient to cut a canal four miles in length, on the summit level between the two rivers; and thereby to unite the Tulpehocken, which falls into the Schuylkill, with the Quitipahilla, a branch of the Swatara, which empties into the Susquehannah. But it was soon ascertained, that the original plan of improving, by a succession of dams, the navigation of those small rivers was erroneous, and that it would be necessary to cut a canal the whole way.

The summit level is at an elevation of 310 feet above the Schuylkill, and of 308 feet above the Susquehannah. Adjacent springs are considered sufficient for the upper locks; and the creeks would, after a short descent, afford an abundant supply. The proposed dimensions of the canal, were a breadth of 20 feet at the bottom, and a depth of three feet and a half; and the expense was estimated at near 1,500,000 dollars.

The work was commenced, the canal has been cut the whole distance of four miles on the summit level; five locks made of brick, have been constructed; land and water rights have been purchased, and a considerable capital has been expended. But although the State

of Pennsylvania, has permitted the company to raise 266,000 dollars by lottery, and is bound to pay to them 300,000 dollars, whenever the work shall have been completed, it remains suspended for want of funds.

The great lockage necessary for this canal, is the principal objection to that line of communication ; and it has been suggested, that a canal from Columbia on the Susquehannah, to tide water, or to the great Delaware and Chesapeake canal, would be much less expensive, and equally beneficial, both to the interior country, and to Philadelphia. This question, as many others suggested in this report cannot be decided by any, but practical and skillful engineers.

IV. *Appomattox.*

A company has been incorporated for opening a canal from the upper end of the falls of that river, which is the south branch of James River, to Petersburgh on the head of the tide. The distance is five miles, and the descent more than thirty feet to a basin about sixty feet above the tide, in which the canal will terminate. The water is drawn from the river ; and the canal, 16 feet wide, 3 feet deep, and admitting boats of six tons, is nearly completed. The capital already expended amounts to sixty thousand dollars. But the company own thirty negroes, and suppose that their labour and a further sum of ten thousand dollars, will be sufficient to build the locks, and to dig about half a mile, which remains to be cut, in order to open the communication between the river and the basin. This work, which has been carried on with much zeal, and at a small expense, will open an important navigation of near 100 miles.

V. *Neuse and Beaufort.*

The harbour of Beaufort, in North-Carolina, and which must not be confounded with that of the same name in South-Carolina, admits vessels drawing eigh-

teen feet of water. Ocracoke Inlet, the only navigable entrance into the Pamtico and Albermarle sounds, that extensive æstuary of the rivers Chowan, Roanoke, Tar, and Neuse, has less water and is miles from Newbern, on the last-mentioned river. The distance between Newport, or Beaufort River, and the Neuse being only three miles, and the elevation of the highest intervening ground no more than seven feet above tide water, a canal uniting the two rivers was undertaken by a company incorporated for that purpose by the State of North-Carolina. All the shares have, from particular circumstances, become the property of one individual; and the work which had been commenced some years ago, is now suspended.

VI. *Cape Fear River.*

A company, incorporated by the same State for improving the navigation of this river, after having exhausted a portion of their funds, which did not exceed twelve thousand dollars in fruitless attempts to improve the natural navigation of the river, have opened a canal with a lock, which opens a safe passage around the Buck-Horn, or Great Falls, seven miles below the junction of the Deep and Haw River. Another canal, six miles in length, with two locks, is necessary around Smilie's Falls. Nearly half that distance has been completed; but the work is now suspended for want of funds. The legislature has lately authorized the company to increase their capital.

VII. *New-Orleans.*

The canal Carondelet, which has already been mentioned, extends from Bayou St. John to the fortifications or ditch of the city, and thereby opens an inland communication with Lake Ponchartrain. A company is incorporated by the Territorial legislature, for the purpose of repairing and improving that work, and of

uniting the canal by locks with the Mississippi. Independent of other advantages, this undertaking would enable government to transport with facility, and use the same naval force for the defence of both the Mississippi and Lake Ponchartrain, the two great avenues by which New-Orleans may be approached from the sea.

TURNPIKE, OR ARTIFICIAL ROADS.

A great number of artificial roads have been completed in the eastern and middle States, at an expense varying from less than one thousand to fourteen thousand dollars a mile. The labour bestowed on the least expensive species consists in shortening the distance, diminishing the ascent of hills, removing rocks, levelling, raising, and giving a proper shape to the bed of the roads, draining them by ditches, and erecting bridges over the intervening streams. But the natural soil of the road is used, instead of covering it with a stratum of gravel or pounded stones.

It appears by one of the papers marked (D), under which letter will be found all the information which has been obtained respecting roads, that fifty turnpike companies have been incorporated, since the year 1803, in the State of Connecticut alone; and that the roads undertaken by those companies are all of that description. Thirty-nine of those roads extending together 770 miles, are completed. The most expensive is that from New-Haven to Hartford, which has cost 79,261 dollars; or, the distance being thirty-four miles and three quarters, at the rate of 2,280 dollars a mile; but about 18,000 dollars of the capital have been expended in the purchase of the land through which the road is carried. The nett income on this road, deducting the annual repairs and expenses from the annual tolls, does not exceed 3,000 dollars. Of six of the roads, which together extend 120 miles, no account has been received. The other thirty-two extend together 615 miles, and have cost only 340,000 dollars; or on an average at the rate of 550 dollars a mile; and it seems that the

aggregate of annual tolls on the whole is 86,000 dollars; from which deducting the annual repairs and expenses amounting to 48,000 dollars, leaves a nett income of 38,000 dollars, or of about 11 per cent. on the capital expended.

No particular account has been received of the roads in the other eastern States; but it is known that, besides some of a similar description with those of the State of Connecticut, several of a more expensive kind have been completed, particularly in Massachusetts. The cost has varied from 3,000 to 14,000 dollars a mile, and, amongst artificial roads of the first grade, may be mentioned those from Boston to Providence, to Salem, and to Newburyport. These are all covered with an artificial stratum of gravel or pounded stones, and finished in the most substantial manner. Great expense has also been incurred in order to shorten the distance without exceeding the angle of ascent, which is fixed at five degrees, and it is stated that the road to Newburyport, 32 miles in length, and in which marshes and rocks presented considerable obstacles, has cost 400,000 dollars, or at the rate of 12,500 dollars a mile. Those expensive roads, however useful and permanent, appear to be much less profitable than those of Connecticut The Salem road is said to yield six per cent.; another road has been stated as yielding eight per cent.; the income of all the others in the State of Massachusetts, is said not to exceed on an average three per centum, and that of the road from Boston to Newburyport amounts to no more than two per cent.

A greater capital has been vested on turnpike roads in the State of New-York than in any other. In less than seven years sixty-seven companies have been incorporated, with a nominal capital of near five millions of dollars, for the purpose of making more than 3,000 miles of artificial roads; and 21 other companies have also been incorporated with a capital of 400,000 dollars, for the purpose of erecting twenty-one toll bridges. Although no particular account has been received, either of the capital actually expended, of the annual

amount of tolls, or of the materials of the roads, it is known that great progress has been made ; and it has been stated that nine hundred miles of road were already completed by 28 companies, whose capital amounted to 1,800,000 dollars, and who had 200 miles of road more to finish.

Those roads extend in every direction, but particularly from every town or village on the North River, westwardly and northwestwardly towards the waters of the Susquehannah, and those of the great lakes. The most expensive is that from Albany to Schenectady, fourteen miles long, and which has cost at the rate of ten thousand dollars a mile. Near one hundred and forty miles of roads, extending westwardly from Albany and Schenectady, appear to have cost at the rate of 2,500 or 3000 dollars a mile. The expense of all the others does not seem on an average to exceed 1,250 dollars a mile.

More detailed information has been obtained respecting the roads in New-Jersey, Pennsylvania, and Maryland.

In New-Jersey a turnpike road has lately been completed from Trenton to Brunswick. The distance is twenty-five miles ; the greatest angle of ascent 3 degrees, and the road is nearly in a straight line, the only considerable obstruction being the "Sand Hills," through which it was necessary to dig at the depth of thirty feet, in order not to exceed the angle of ascent.— The road is 36 feet wide, fifteen feet of which are covered with about six inches of gravel. A few wooden bridges, with stone abutments and piers, have been erected across the intervening streams. The whole expense is stated at 2,500 dollars a mile. From Brunswick, the road will be extended to Elizabethtown, and the work is now progressing. Another road has been undertaken in the same state, from Brunswick to Easton, on the river Delaware. The distance is 43 miles, of which eleven have been completed at an expense of 40,000 dolls. This road will be more expensive than the preceding, both on account of the ground, the bridges being more numerous, and the Blue Ridge (Musconekong Moun-

tain) intervening; and because a more substantial facing or greater thickness of gravel is requisite. The funds of the company are exhausted.

In Pennsylvania, artificial roads of the most substantial kind have been completed, or are progressing from Philadelphia, in sundry directions.

The principal are to Bristol and Trenton, twelve miles of which are completed; to Germantown and Perkiomen, with two branches; to Willow Grove and to Chesnut Hill; and to Lancaster and Columbia, with a branch to Harrisburgh.

The distance from Philadelphia to Perkiomen is 25 miles and a quarter; the two branches extend, one ten miles and the other 7 miles and a half; making together near 43 miles. The angle of ascent is 4 degrees; the breadth of the road 50 feet, of which 28 feet, having a convexity of 15 inches, are covered with a stratum either of gravel 18 inches thick, or of pounded stones 12 inches thick. One half of the stones forming the lower part of the stratum, are broken into pieces not more than five inches in diameter. The other half or upper part of the stratum, consists of stones broken into pieces not more than two inches and a half in diameter: and this difference in the size of the stones is represented as a considerable defect. Side or summer roads extend on each side of the gravel or stone road. The 5 miles next to Philadelphia, have cost at the rate of $ 14,517 a mile: the other 20 1-2 miles at the rate of $ 10,490 a mile. Yet there were no natural impediments, and only small bridges or culverts were necessary. The capital expended on these 25 miles and a half is 285,000 dollars: the tolls amount to 19,000 dollars: the annual repairs and expenses to 10,000 dollars: the nett income to about 9,000 dollars, or little more than 3 per cent. on the capital expended.

The distance from the Schuylkill, at Philadelphia to Lancaster is 62 miles and a quarter. Exclusively of the side or summer roads, twenty-four feet of the bed of the road are covered with a stratum of pounded stones eighteen inches thick in the middle of the road, and de-

creasing each way to 12 inches. The Valley Hills are the most elevated and steep on the road ; but the angle of ascent no where exceeds 4 degrees. Stone bridges have been erected across all the intervening streams.— That across the river Conestogo consisting of nine arches is private property ; and the most expensive built by the company is that across the Brandywine, consisting of three arches of solid masonry, and which cost twelve thousand dollars. The capital of the company amounted to 360,000 dollars ; but this being insufficient it became necessary to apply a considerable portion of the tolls to the completion of the work. The whole expense amounts to 465,000 dollars, or at the rate of about 7500 dollars a mile. The annual tolls have not yet exceeded 25,000 dollars ; and the annual repairs and expenses are estimated at 13,000, leaving a nett income of about 12 000 dollars. The prospect of an increased profit, derived from the proposed extension of the road, has however raised the price of that stock nearly to par.

The Lancaster road, the first extensive turnpike that was completed in the United States, is the first link of the great western communication from Philadelphia — It has been extended ten miles westwardly to Columbia on the Susquehannah ; and another branch is now progressing northwestwardly to Harrisburgh, also on the Susquehannah, and thirty-six miles from Lancaster.— The State of Pennsylvania has also incorporated two companies in order to extend the road by two different routes as far as Pittsburgh on the Ohio, and near 300 miles from Philadelphia. The southern route following the main post-road, passes by Bedford and Somerset.— The northern route passes by Huntingdon and Frankstown, the highest point to which the Juniata branch of the Susquehannah is navigable. To this route the state has authorized the subscription of one hundred thousand dollars.

Other roads in a north-west direction from Philadelphia towards the Gennessee and Presque Isle on Lake Erie are also progressing, and have been encouraged by the subscriptions or donations of the legislature. They

are generally on a much less extensive plan, than those in the direction of Pittsburgh. A section of thirty miles from Lausanne on the Lehigh to Nescopeck on the Susquehannah has been completed at the expense of thirty-six thousand dollars, by a company; and it is intended to extend it seventy miles further to Newton on the Tioga branch of the Susquehannah.

In Maryland, roads extending from Baltimore in various directions have lately been undartaken by several companies, and are rapidly progressing. On the falls turnpike, which extends in a northerly direction, about four miles of a road 22 feet wide, covered with a stratum of pounded stones 10 inches thick, and having an ascent not exceeding 4 degrees, have been completed at the rate of 7,500 dollars a mile.

The "Reister Town" turnpike, in a north-westwardly direction, extends 16 miles to that village; whence two branches extending, one 19 and the other 29 miles further, will enter Pennsylvania, at two different places. The road 24 feet wide is covered with a stratum 12 inches thick, of pounded stones not more than three inches in diameter. The angle of ascent does not exceed three degrees and a half. Ten miles have been completed at the expense of 10,000 dollars a mile, and the work is progressing. The capital of the company amounts to 420,000 dollars.

The capital of the "Frederick Town" turnpike company amounts to 500,000 dollars; and the company is authorized to open the great western road, as far as Boonsborough, beyond the Blue Ridge, and 62 miles from Baltimore. The angle of ascent will not exceed 4 degrees; the road has a convexity of 9 inches, and on a breadth of 22 feet, is covered with a stratum 10 inches thick of pounded stones not exceeding 3 inches in diameter, over which are spread 2 inches of gravel or coarse sand. The first 20 miles next to Baltimore, have cost at the rate of 9,000 dollars, and the next 17 miles are contracted for at the rate of 7,000 dollars a mile.

The distance from Boonsborough to Cumberland, at the foot of the Alleghany mountain, following the pre-

sent road, is 73 miles; and, although the company is not yet authorized to extend the turnpike to that place, the ground has been surveyed, and it is ascertained that the road may be continued with an angle of ascent not exceeding 4 degrees. The ascent of the road laid out by the United States, from Cumberland to Brownsville, on the Monongahela, does not exceed 5 degrees, and the distance is 72 miles; making the whole distance of a turnpike road from Baltimore to the navigable waters of the Ohio, 207 miles. The distance from the city of Washington to the same spot on the Monongahela, is some miles shorter, being, as has already been stated, the shortest communication between tide water, and the navigable western waters.

South of the Potomack, few artificial roads have been undertaken. From Alexandria, one is now progressing in a north-westwardly direction, towards Middleburgh. Another has lately been commenced, from Richmond to Ross' coal mine.—But the only one which, so far as any accounts have been received, is completed, extends 12 miles from Manchester, opposite to Richmond, in a westwardly direction to the coal mines of Falling Creek. This road, 36 feet wide, is gravelled, and has cost 50,000 dollars; but the last four miles did not cost more than at the rate of 3,000 dollars a mile.—Yet it is sufficiently substantial, the route being very level, to admit waggons carrying four tons.

The greater progress made in the improvement of roads in the northern parts of the Union, must be principally ascribed to a more compact population, which renders those improvements more necessary, and at the same time supplies with greater facility the means of effecting them. The same difference is perceptible in the number of bridges erected in the several States.

In the eastern States, and particularly Massachusetts, wooden bridges uniting boldness to elegance, and having no defect but want of durability, have been erected over the broadest and deepest rivers. In the lower counties of Pennsylvania, stone bridges are generally found across all the small streams. Both in that State

and at some distance eastwardly, bridges with stone piers and abutments, and a wooden superstructure, are common over wide rivers. Of these, the most expensive, and which may be considered as first in the United States, is the permanent Schuylkill bridge near Philadelphia, erected by a company at an expense of 300,000 dollars. Its length, including the abutments, does not exceed 750 feet, and it is supported only by two piers and the abutments. But those piers, 195 feet apart, are of the most solid workmanship, and one of them was sunk at a depth of more than 24 feet below low water.—The bridge is 42 feet wide, and the wooden superstructure is enclosed and covered with a shingle roof.

The want of bridges south of Pennsylvania, even on the main post road, is sensibly felt. One lately thrown across the Potomack, three miles above the city of Washington, and which, without any intervening piers, is wholly suspended to iron chains extending from bank to bank, deserves notice, on account of the boldness of its construction, and of its comparative cheapness. The principle of this new plan, derived from the tenacity of iron, seems applicable to all rapid streams of a moderate breadth.

The general principles of improved roads seem to be, 1st, the reduction of hills, by diminishing the angle of ascent, which ought not to exceed, whenever practicable, three degrees and a half, and under no circumstances, five degrees: 2dly, a sufficient convexity in the bed of the road, together with ditches and drains, all which are intended to prevent the injury caused by standing water or freshets: 3d, an artificial bed of pounded stones or gravel sufficiently substantial to support the weight of the carriages in general use on the road, either for the conveyance of persons, or for the transportation of merchandise.

On the last point it appears from the facts already stated, or scattered in the communications received on that subject: 1st, that the stones ought to be similar in quality and reduced to the same size, which should not exceed three inches in diameter; 2d, that the prefera-

ble qualities of stone, rank, in the following order: hard black stone, granite, flint or quartz, blue lime stone, white do.: 3d, that the stratum may be either of pounded stones, 12 inches thick, or of pounded stones 10 inches thick, with two inches of gravel spread over the stones; or entirely of gravel 18 inches thick: 4th, that when the materials are equally convenient, the expense of those three modes will not materially differ, but that the rate of expense depends principally on the number of hills and bridges, distance of materials, breadth of the road, and price of labour: and 5th, that the general adoption of broad wheels for the transportation of heavy loads, is necessary to the full enjoyment of the advantages expected from the most substantial artificial roads. On the degree of convexity and on the proper shape to be given to the natural bed of the road, under the artificial stratum, a diversity of opinions seem to prevail.

The roads heretofore made may be divided into three general classes.

1. Those where the only improvement consists in the reduction of hills, and in the convexity and ditches of the road, whereby the angle of ascent is rendered more easy and standing water excluded; but where the natural soil is used without any artificial stratum. The expense of these roads may vary according to local circumstances, and the perfection of the work, from five hundred to one thousand dollars a mile. They are most generally in use in the eastern States, and may be introduced with advantage in all those districts of country where wealth does not admit more expensive improvements, or where the materials of an artificial stratum are altogether wanting. It is only in the last case that they may be considered as a national object; and no other improvement besides bridges and causeways is, perhaps, practicable in the lower country of the southern States. Iron, and even timber rail roads, may, however, be sometimes substituted in those level parts of the country, where stones and gravel are not to be found.

2. Roads prepared as above, of a reduced breadth, and covered with a thin coat of gravel not more than six or nine inches thick ; such as the turnpike lately made between Trenton and Brunswick. These roads, the expense of which may be estimated at about 3,000 dollars a mile, may be used wherever the frost does not materially affect them, and in every climate, when they are intended principally for the conveyance of persons, and not for the transportation of heavy loads.

3. The artificial roads of the best construction, such as have been already described. These, when not exceeding 22 feet in breadth, and except in the vicinity of large cities, will cost at the rate of 7,000 dollars a mile, exclusively of bridges over large rivers. And they must be resorted to, whenever a *commercial* road for heavy transportation is intended, particularly in the middle States, or rather in the United States, between 41 and 36 degrees of north latitude. North of the 41st degree the snow lies generally during the whole winter ; and the great bulk of heavy transportation is effected in sleighs during that season. There is, therefore, less necessity for using the roads in the spring ; and they are also better protected against the effects of the frost by the snow. South of the 36th degree, which, in the Atlantic States, may be considered as the boundary of the great cotton cultivation, the frost does not materially injure the roads. It is between those two extremes that the most substantial are required ; and it also happens that the great land communications with the western country, which considerably increase the amount of transportation, are principally within the same limits.

The same principles which have directed the arrangement adopted in this report in relation to canals, will also point out those roads which seem in the first instance to claim the patronage of the general government.

Those which appear most necessary for the communications between the Atlantic and western rivers have already been mentioned, under that head ; and the improvement of the water communica-

North River and the great lakes ought to take the precedence of any other in that direction.

That road which, therefore seems exclusively to claim public attention, is a great turnpike extending from Maine to Georgia in the general direction of the sea-coast and main post-road, and passing through all the principal sea-ports. The general convenience and importance of such a work are too obvious to require any comments: and the expense seems to be the primary object of consideration.

The distance will be roughly estimated at 1,600 miles; and from what has been stated on the subject of roads generally, it may be inferred that the greater part of the road being intended almost exclusively for travelling, and not for transportation of heavy articles, the expense cannot exceed the rate of 3,000 dollars a mile. For although some detached portions of the route, being commercial roads, must be improved as such, and at a greater expense, an equivalent reduction in other parts will result from those portions which are already improved by private companies, and from the impossibility, for want of materials for an artificial stratum, of going in some places beyond what has been described as the first or cheapest species of turnpikes. The whole expense may therefore be estimated at 4,800,000 dollars.

A secondary object, but of more importance to government than to individuals, would be the improvement, on a much less expensive scale, of certain portion of roads leading to some points on the extremes of the union, intended principally for the purpose of accelerating the progress of the mail, and the prompt transmission of information of a public nature. The points contemplated are Detroit, St. Louis, in Upper Louisiana, and New-Orleans. The portions of road which, traversing a wilderness, cannot be improved without the aid of the United States are, from the Tuscarora branch of the Muskingum to Detroit; from Cincinnati, by Vincennes, to St. Louis; and from Nashville, in Tennessee, or Athens, in Georgia, to Natches. The expense necessa-

ry to enable the mail, and even stages, to proceed at the rate of 80 miles a day, may, at the rate of about 200 dollars a mile, including bridges over all the small streams, be estimated for those three roads, at 200,000 dollars.

RECAPITULATION AND RESOURCES.

The improvements which have been respectfully suggested as most important, in order to facilitate the communication between the great geographical divisions of the United States, will now be recapitulated; and their expense compared with the resources applicable to that object.

I. From north to south, in a direction parallel to the sea coast.

	Dollars.	
1. Canals opening an inland navigation for sea vessels from Massachusetts to North-Carolina, being more than two thirds of the Atlantic sea-coast of the United States, and across all the principal capes, cape Fear Excepted,	3,000,000	
2. A great turnpike road from Maine to Georgia, along the whole extent of the Atlantic sea coast,	4,800,000	
		7,800,000

II. From east to west, forming communications across the mountains between the Atlantic and western waters:

1. Improvement of the navigation of four great Atlantic rivers, including canals parallel to them,	1,500,000	
2. Four first rate turnpike roads from those rivers across the mountains, to the four corresponding		

	Dollars.	
Brought forward,		7,800,000
western rivers,	2,800,000	
3. Canal around the falls of the Ohio,	300,000	
4. Improvement of roads to Detroit, St. Louis, and New-Orleans,	200,000	
		4,800,000

III. In a northern and northwestardly direction, forming inland navigations between the Atlantic seacoast, and the great lakes and the St. Lawrence:

1. Inland navigation between the North River and Lake Champlain,	800,000	
2. Great inland navigation opened the whole way by canals, from the North River to Lake Ontario,	2,200,000	
3. Canal around the falls and rapids of Niagara, opening a sloop navigation from Lake Ontario to the upper lakes, as far as the extremities of Lake Michigan,	1,000.000	
		4,000.000
Making together,		$ 16 600 000

IV. The great geographical features of the country have been solely adhered to in pointing out those lines of communication: and these appear to embrace all the great interests of the Union, and to be calculated to diffuse and increase the national wealth in a very general way, by opening an intercourse between the remotest extremes of the United States. Yet it must necessarily result from an adherence to that principle, that those parts of the Atlantic States through which the great western and north-west communications will be carried, must, in addition to the general advantages in which they will participate, receive from those commu-

nications greater local and immediate benefits than the eastern, and perhaps southern States. As the expense must be defrayed from the general funds of the Union, justice, and perhaps policy not less than justice, seem to require that a number of local improvements, sufficient to equalize the advantages, should also be undertaken in those States, parts of States or districts, which are less immediately interested in those inland communications. Arithmetical precision cannot, indeed, be obtained in objects of that kind; nor would an apportionment of the moneys applied, according to the population of each State, be either just or practicable; since roads, and particularly canals, are often of greater utility to the States which they unite than to those through which they pass. But a sufficient number of local improvements, consisting either of roads or canals, may, without any material difficulty, be selected so as to do substantial justice, and give general satisfaction. Without pretending to suggest what would be the additional sum necessary for that object, it will, for the sake of round numbers, be estimated at 3,400,000

Which, added to the sum estimated for general improvements, 16.600.000

Would make an aggregate of 20 millions of dollars, 20.000 000

An annual appropriation of two millions of dollars would accomplish all those great objects in ten years, and may, without inconvenience, be supplied in time of peace by the existing revenues and resources of the United States. This may be exemplified in several ways.

The annual appropriation on account of the principal and interest of the public debt has, during the last six years, amounted to eight millions of dollars. After the present year, or, at furthest, after the ensuing year, the sum which, on account of the irredeemable nature of the remaining debt, may be applied to that object cannot, in any one year, exceed 4,600,000 dollars, leaving,

therefore, from that source alone, an annual surplus of 3,400 000 dollars, applicable to any other object.

From the first of January, 1801, to the first of January, 1809, a period of eight years, the United States shall have discharged about thirty-four millions of the principal of the old debt, or deducting the Louisiana debt, incurred during the same period and not yet discharged, about twenty-three millions of dollars. They may with equal facility apply, in a period of ten years, a sum of twenty millions of dollars to internal improvements.

The annual permanent revenue of the United States, calculated on a state of general peace, and on the most moderate estimate, was, in a report made to Congress on the sixth day of December, 1806 computed for the years 1809—1815, at 14 millions of dollars. The annual expenses on the peace establishment, and including the four millions six hundred thousand dollars on account of the debt, and four hundred thousand dollars for contingencies, do not exceed eight millions and a half, leaving an annual surplus of five millions and a half of dollars. To provide for the protection and defence of the country is undoubtedly the object to which the resources of the United States must, in the first instance, be applied, and to the exclusion of all others, if the times shall require it. But it is believed that in times of peace—and to such period only are these remarks applicable—the surplus will be amply sufficient to defray the expenses of all the preparatory measures of a permanent nature which prudence may suggest, and to pay the sum destined for internal improvements. Three millions annually applied during the same period of ten years, would arm every man in the United States, fill the public arsenals and magazines, erect every battery and fortification which could be manned, and even if thought eligible build a navy. That the whole surplus would be inadequate to the support of any considerable increase of the land or naval force, kept in actual service in time of peace, will be readily admitted. But such a system is not contemplated; if ever adopted, the objects of this report must probably be abandoned. For

it has not heretofore been found an easy task for any government to indulge in that species of expenses which, leaving no trace behind it, adds nothing to the real strength of the country, and at the same time to provide for either its permanent defence or improvement.

It must not be omitted that the facility of communications constitutes, particularly in the United States, an important branch of national defence. Their extensive territory opposes a powerful obstacle to the progress of an enemy. But, on the other hand, the number of regular forces which may be raised, necessarily limited by the population, will for many years be inconsiderable when compared with that extent of territory. That defect cannot otherwise be supplied than by those great national improvements, which will afford the means of a rapid concentration of that regular force, and of a formidable body of militia on any given point.

Amongst the resources of the Union, there is one, which, from its nature, seems more particularly applicable to the internal improvements. Exclusively of Louisiana, the general government possesses, in trust for the people of the United States, about one hundred millions of acres fit for cultivation, north of the river Ohio; and near fifty millions south of the State of Tennessee. For the disposition of those lands a plan has been adopted, calculated to enable every industrious citizen to become a freeholder, to secure indisputable titles to the purchasers, to obtain a national revenue, and, above all, to suppress monopoly. Its success has surpassed that of every former attempt, and exceeded the expectations of its authors. But a higher price than had usually been paid for waste lands by the first inhabitants of the frontier became an unavoidable ingredient of a system intended for general benefit, and was necessary, in order to prevent the public lands being engrossed by individuals, possessing greater wealth, activity, or local advantages. It is believed that nothing could be more gratifying to the purchasers, and to the inhabitants of the western States generally, or better calculated to

remove popular objections, and to defeat insidious efforts, than the application of the proceeds of the sales to improvements, conferring general advantages on the nation, and an immediate benefit on the purchasers, and inhabitants themselves. It may be added, that the United States considered merely as owners of the soil, are also deeply interested in the opening of those communications, which must necessarily enhance the value of their property. Thus the opening of an inland navigation, from tide water to the great lakes, would immediately give to the great body of lands, bordering on those lakes as great value, as if they were situated at the distance of one hundred miles by lands, from the sea coast. And if the proceeds of the first ten millions of acres, which may be sold, were applied to such improvements, the United States would be amply repaid, in the sale of the other ninety millions.

The annual appropriation of two millions of dollars, drawn from the general revenues of the Union, which has been suggested, could operate to its full extent, only in times of peace, and under prosperous circumstances. The application of the proceeds of the sales of the public lands might, perhaps, be made permanent until it had amounted to a certain sum, and until the most important improvements had been effected. The fund created by those improvements, the expense of which has been estimated at twenty millions of dollars, would afterwards become itself a perpetual resource for further improvements. Although some of those first communications should not become immediately productive, and although the same liberal policy, which dictated the measure, would consider them less as objects of revenue to government, than of increased wealth, and general convenience to the nation, yet they would all sooner or later acquire, as productive property, their par value. Whenever that had taken place in relation to any of them, the stock might be sold to individuals or companies, and the proceeds applied to a new improvement. And by persevering in that plan, a succession of improvements would be effected, until every portion

of the United States, should enjoy all the advantages of inland navigation and improved roads, of which it was susceptible. To effect that great object, a disbursement of twenty millions of dollars, applied with more or less rapidity, according to the circumstances of the United States, would be amply sufficient.

The manner in which the public moneys may be applied to such objects, remains to be considered.

It is evident that the United States cannot, under the constitution, open any road or canal, without the consent of the State through which such road or canal must pass. In order therefore to remove every impediment to a national plan of internal improvements, an amendment to the constitution was suggested by the executive, when the subject was recommended to the consideration of congress. Until this be obtained, the assent of the states being necessary for each improvement, the modifications under which that assent may be given will necessarily control the manner of applying the money. It may be however observed, that, in relation to the specific improvements which have been suggested, there is hardly any which is not either already authorized by the States respectively, or so immediately beneficial to them as to render it highly probable, that no material difficulty will be experienced in that respect.

The moneys may be applied in two different manners. The United States may, with the assent of the States, undertake some of the works at their sole expense, or they may subscribe a certain number of shares, of the stock of companies incorporated for the purpose. Loans might also in some instances be made to such companies. The first mode would, perhaps, by effectually controling local interests, give the most proper general direction to the work. Its details would probably be executed on a more economical plan by private companies. Both modes may perhaps be blended together, so as to obtain the advantages pertaining to each. But the modifications of which the plan is susceptible, must vary according to the nature of the work, and of the charters, and seem to belong to that class of details,

which are not the immediate subject of consideration.

At present, the only work undertaken by the United States, at their sole expense, and to which the assent of the States has been obtained, is the road, from Cumberland to Brownsville. An appropriation may for that purpose be made at any time. In relation to all other works, the United States have nothing at this time in their power, but to assist those already authorized; either by loans, or by becoming stock-holders; and the last mode appears the most eligible. The only companies incorporated for effecting some of the improvements considered in this report, as of national and first rate importance, which have applied for such assistance, are the Chesapeake and Delaware Canal, the Susquehannah Canal, and the Dismal Swamp Companies; and authority might be given to subscribe a certain number of shares to each, on condition, that the plan of the work to be executed should be approved by the general government. A subscription to the Ohio canal, to the Pittsburgh road, and perhaps to some other objects not fully ascertained, is also practicable at this time.

As an important basis of the general system, an immediate authority might also be given to take the surveys and levels of the routes of the most important roads and canals which are contemplated; a work always useful, and by which the practicability and expense of the undertakings would be ascertained with much more correctness than in this report. A moderate appropriation would be sufficient for those several objects.

In the selection of the objects submitted in obedience to the order of the Senate as claiming in the first instance the aid of the general governmement, general principles have been adhered to as best calculated to suppress every bias of partiality to particular objects.—Yet some such bias, of which no individual is perfectly free, may, without being felt have operated on this report. The national legislature alone, embracing eve local interest, and superior to every local considerati is competent to the selection of such national objec The materials contained in the papers herewith tra

mitted, and the information to be derived from surveys taken under the authority of the general government, will furnish the facts necessary for a correct decision.—Two communications by Mr. B. H. Latrobe, and by Mr. Robert Fulton, marked E, and F, are in the meanwhile respectfully referred to, as containing much interesting practical information, connected with observations of a general nature on the subject.

All which is respectfully submitted.

ALBERT GALLATIN,
Secretary of the Treasury.

Treasury Department,
4th April, 1808.

Mr. Latrobe's Communication.

[E.]

Washington, March 16, 1808.

SIR,

I have the honour of your letter of the 29th of July, 1807, transmitting to me a copy of the resolution of the Senate of the United States of the 2d of March, 1807, together with a list of queries respecting artificial navigations and canals, to which you request my answer and opinion.

In order to give you all the information on this subject which you wish and I possess, and in the most condensed form, I ask your permission to depart from the order which your questions demand, and after treating the subject generally, to enter upon an account of those works, in detail, with which my personal experience has made me more particularly acquainted.

The most striking circumstance in a view of the Atlantic States of the Union, in relation to the improvement of their internal navigation, is the uniformity of the natural arrangement of the rivers and mountains, and that this arrangement differs from that of every other country in which artificial navigation has been attempted.

In other countries, the general course of all the rivers, is between the mountains, and along the valleys; in this, the general course of all the rivers is across that of the mountains and of the valleys.—Our mountains, from their termination to the south-west, in Georgia, hold a course to the east of north. The general direction of our principal rivers is to the east of south; and on inspection of the map it will be observed that, as the direction of the mountains to the north east of the Delaware becomes more easterly, so do our rivers acquire a more

southern course, always crossing the mountains at nearly the same angle.

Our rivers may be divided into three classes: *Primary rivers*, that discharge their waters immediately into the ocean. Of these the relative magnitude might be rated according to the surface they respectively drain. *Secondary rivers*, or such as fall into the first, above their tide water; and *Crecks*, properly so called, which rise below the falls of the first rivers, or rather collect the water of the level land, below the falls, and discharge it into the tide waters.

Of our primary rivers, the Susquehannah is the principal. By a great degree of geographical injustice, this mighty river loses its name at the foot of its falls, and is called the Chesapeake Bay, from thence to the ocean; although its width, compared with its length, forbids the term of bay to be applied to what is called the Chesapeake. All of these rivers cross, in the greatest part of their course, the direction of the mountains.

Of the secondary rivers, many of which are of great importance and magnitude, some, and perhaps the greatest number, hold a course parallel to the mountains; as the Shenandoah, the Conogocheague, the Lehigh, &c. draining the valleys and receiving away the torrents of the mountains.

The third order of our water courses rise either in the lowest ridge of our hills, which I will call the granite ridge, and over which all our principal rivers, from Georgia to the Hudson, fall, and then run through the alluvial country which lies between the granite ridge and the ocean. Such rivers are, the Nottaway, the Blackwater, the Meherrin, the Anacosta, (eastern branch of Potomack,) the Elk River, and the very important creek in the State of Delaware, the Christiana; or they are merely drains of the alluvial country, assuming an appearance of importance below the head of the tide, above which they are mere torrents, almost dry in the autumn. Such streams are all the rivers of the eastern shore of the Chesapeake, and of the lower part of the Jerseys, and innumerable water courses, forming large æstuaries in the southern states.

Our great north-western lakes, from their first source to the eastern end of Lake Erie, may be considered as part of the great river St. Lawrence, following the direction of the rest of our rivers, until opposed by the northern extremity of the Alleghany. From thence its course follows the valley west of the Alleghany through lake Ontario to the ocean, receiving the waters of the northern extremity of the mountain in its course.

This general view of the construction of our country was necessary, in order to understand the general principles on which our artificial navigation can be so conducted as to be useful or even practicable, and to explain why connexions of waters which, on the map appear advantageous and feasible, would be useless, and perhaps impracticable by any effort of art.

Two principal objects will dictate all the exertions toward the improvement of our internal navigation, which can, for many years to come, be attempted; 1. To carry our produce by water to the nearest port for its exportation, and the importation of foreign articles; 2. To exchange, by internal commerce, the articles reciprocally deficient on lines parallel to the sea-coast. Canals, the use of which arises from manufacturing activity, will not probably be soon required.

The first object, as all our principal rivers run seaward, and generally by the shortest course, must be attained by the natural or improved navigation of the rivers themselves, or by canals cut parallel to them; the second, may often require a navigation parallel to the valleys, so as to communicate one principal river with another.

The former attempt at improved navigation has already been made on many of our principal rivers; the latter has been seldomer undertaken; and only once above the falls of both primary rivers, in the canal intended to join the Susquehannah and Schuylkill, and the Schuylkill and Delaware Rivers, above Philadelphia.

The general construction of our country opposes to artificial navigation, in either of these directions, difficulties which in no part of the world exist in so uniform

and certain a degree. Canals parallel to our rivers have three formidable obstacles to encounter and overcome.

1. The rapid descent of the ravine cut through the mountains by the river itself, along which the canal must be carried; or if the ravine be quitted, difficulties on the high levels which, the further you go from the river, are always intersected by the more numerous ravines, and embarrassed by the difficulty of returning to the ravine of the river.

2. The invariably rocky nature of the ground, which is uniformly of granite in all its varieties; and the numerous fissures which carry off the water, and require lining.

3. The difficulty of keeping off the land water, and of crossing the lateral branches and torrents of the river.

On the other hand, canals parallel to our mountains, must necessarily cross the ridge or spur of the mountain which divides the waters of two primary rivers.—On this ridge above the falls, the water requisite to supply the canal is always scanty—often there is none; and though a tunnel, or a steam-engine, or, in the last resort, a rail road, are certain means of obviating the difficulty, they are expensive, inconvenient, and imperfect. Below the granite ridge the difficulty is less. There may always be found a supply of water from the ridge itself, and the feeders, though carried through rocky and expensive ground, are themselves useful as small canals, as far as they extend; and besides, below the ridge the soil is easily cut and embanked.

Having so frequently mentioned the granite ridge, I will here trace its extent as far as my knowledge of our country enables me to do it.

The granite ridge forms the shore of the north side of Long-Island, opposite to the island of New-York. All the south of the island is alluvial, and is the first margin of alluvial soil below the granite ridge. This margin of alluvial soil beginning at Long-Island widens as it extends to the south-west, until in Georgia it becomes more than 200 miles in width.

Staten-Island and Bergen Point are two spurs of the same ridge, which continues nearly in the line of the post-road to Trenton, where the river Delaware falls over it, having worn down the rocks more deeply there than in many other of our rivers. The Delaware runs in its general direction for 60 miles under the foot of the ridge as far as New-castle, leaving it only for a short distance at particular bends of the river. At Philadelphia the ridge crosses the Peninsula to Gray's Ferry on Schuylkill. The softer granite of Schuylkill has been worn down so as that the falls are four miles from its lower edge. From Philadelphia the ridge runs with the post road to Havre de Grace, where it is visible on both shores, although the tides extend 6 miles above, to the foot of the falls.

The Susquehannah, by the name of the Chesapeake, may be considered as running under the foot of the granite ridge, almost as far as Baltimore, which city is built upon the foot of the ridge. At the river Patuxent, on the post-road, the ridge appears again, but is lost under the incumbent soil, and is not again visible until it appears at Georgetown. The harder granite of the Potomack has resisted the force of the water more than the granite further to the north east, and the tide reaches only three miles above its outrunnings. From the Potomack the falls of Rappahannock at Fredericksburgh, of James River at Richmond; Appomattox at Petersburgh, Roanoke at Halifax, beyond which point my personal observation does not extend, point out the course of this ridge in a line nearly parallel to the Blue Ridge, diverging to the eastward as it extends southward.

I. *Of the improvement of the natural navigation of our rivers leading to the sea, and the canals cut parallel to them.*

The natural difficulties of the navigation of our rivers are—in the spring, the danger of wreck in the wild wa-

ter of our rapids ; in autumn the obstructions created by rocky shoals,—and, in most of them, rapids and falls, impracticable at all times. The least expensive and most obvious means of removing the former are the blowing the most prominent rocks so as to straiten the channel, and procure a passage at low water.—This has in almost all our rivers been attempted on a greater or less scale, and with various degrees of success. When injudiciously performed, and in rivers of rapid descent, and liable to great variation in the quantity of their water, more injury has been done than advantage obtained. Many of our worst obstructions act as natural dams, which holding up the water, create a large extent of excellent navigation above them. Of this the James River above Westham, and the Susquehannah above Chickisalunga and Hunter's Falls are instances in point. Such obstructions when removed, let down the water rapidly from above, without supplying deeper navigation below.

In a river of much magnitude, as the Susquehannah, indeed no gap or sluice artificially cut can materially affect the rapidity of the stream, but in lesser rivers great care is required, not only to prevent lowering the water above, but to avoid giving a new direction to the current more mischievous in its effects than that which has been changed. But with whatever judgment the natural navigation of a river perplexed by rapids and shoals may be conducted, and however its descent may be thereby facilitated, its descent cannot possibly be rendered more easy, in the same degree. Thus, for instance, although by the moneys expended by the State of Pennsylvania and the Susquehannah canal company on the natural navigation of the Susquehannah below Wright's ferry, it has been rendered much less dangerous to run down the distance of 41 miles, almost the whole of which is a tremendous rapid, from Columbia to the tide and thereby to carry lumber, iron, and agricultural produce to Havre de Grace, and thence to Baltimore,—yet so difficult is the upstream navigation by the same route, even with the assistance of the Susquehannah canal,

that the returns in imported articles have been generally purchased in Philadelphia and conveyed to Columbia or Middletown above the rapids, by the Lancaster turnpike, thence to be boated to the country watered by the upper branches of the Susquehannah. And although the Philadelphia market has hitherto offered more advantages to the buyers of imported goods than that of Baltimore, yet the expense of transporting them 72 miles by land to Columbia, would, if there were a good navigation from Havre de Grace upwards, destroy this advantage.

The difficulty of carrying canals parallel to our great rivers, the scarcity of engineers possessing knowledge and integrity, the want of capital, and above all the erroneous dread of bold measures, and the fear of uselessly expending money on works hitherto unknown among us, has deterred those interested in improving our navigation, from deserting the beds of our rivers, while it was practicable to keep them.—They have therefore had recourse to canals, only where navigation was otherwise impossible—where obstructed by rocks, or broken by a cascade.

There cannot, however, be a reasonable doubt that, if in England, where, compared with the United States, the quantity of water in the rivers varies little between the driest and the wettest period of the year, a canal running parallel to a river, furnishes a much more certain and safe, and equal, and cheap navigation than the river itself, it is infinitely more the case here. Unfortunately those of our canals which have been cut to pass the rapids and falls of our rivers, partake, in a great measure, of the inconveniences of the rivers themselves: some wanting water, when the river is low; some incapable of being entered, excepting at a particular height of the water in the river; some subject to constant accumulation of bars; and all, of those with which I am acquainted, much less useful than the money expended on them ought to have made them.

Those canals of which I now particularly speak are, the James-River Canal, the Potomack Canal, the Conewago and Susquehannah Canals. Of the canals north

of the Delaware and south of Virginia, I have not sufficient knowledge ; nor can I speak of the Appomattox Canal. It is, I believe, not liable to the same strictures in all points which I shall make upon the others ; but though I am well acquainted with the ground, I have not seen the manner in which the work has been executed.

One great and fatal error has been interwoven into the scheme of the other canals, excepting only that of the Potomack. They have been dug as much with a view to the erection of mills as to the purposes of navigation. To fit them for mill races, their descent is rapid and their current strong. They are liable of course to the variation of the quantity of water in the river ; they bring down with their current the alluvium of the river ; bars are formed in them, as well by this alluvium as by the land-wash ; and their banks, where they are not of rock, or walled, are liable to perpetual wear by the current. The canal is, besides, itself an inconvenient rapid to those who would ascend it.

Besides these inconveniences, the contracts binding the company to furnish to the millers the water when it rises above a certain gageselle, for an annual rent, or on other fixed and permanent terms, binds the canal company to the original construction of the work and forbids future improvement. For instance, if a lock were found to be useful above the highest mill it could not be erected, because it would rob the mills below of their stipulated water ; the inclination of the canal cannot be lessened, because it would have the same effect. In the James-River Canal, more than in any other which I have seen, this error, though now generally considered as a very great advantage, will in some future period be discovered and deplored. The Potomack Canal, more especially that of the Little Falls, has the same effect, of a too rapid descent, although the object of a mill race is placed by their charter out of view. But its principal defect is of another kind ; to which that of James River is also, but in a less degree, subject. It receives the wash of all the hills and

ravines of the north bank ; which ought to be discharged through culverts or carried over bridges ; and that legislative impartiality which has required the canal to enter the river at the very head of the tide, in order that Virginia might have an equal chance of becoming the depot of its commerce with Maryland, has very much injured its utility to the country at large.

In a still greater degree than the Potomack Canal, the Susquehannah Canal, beginning at the Maryland and Pennsylvania line, and ending at the head of the tide, has the defect not only of receiving the land-wash of the hills and ravines, but also two considerable rivers, the Conewingo and Octorara, partaking thus of all the danger arising from their inundations, and receiving their alluvium. This canal is also applied to the purposes of a mill race. Other inconveniences attend it which arise from the most unfriendly nature of the river, and the local feelings of the State legislatures of Pennsylvania and Maryland, at the period of the incorporation of the company.

The Conewago Canal, about 150 miles higher up the Susquehannah, is also a mill race, and is the property of an individual. It is of difficult entrance, which is to be regretted, as it ought to be the means of passing a short but very dangerous fall of the river, interrupting a long extent of very good navigation.

Having thus pointed out the general and common defects of these canals, to which I may add, the general want of proper slopes to their banks, I will now enter upon the very thankless task of giving an honest opinion respecting them in detail, viewing only the *public interest ;* and perfectly conscious of the bearing of what I shall say upon private feelings. These feelings however are extremely short-sighted, for nothing could be more advantageous to the individuals most interested, than those measures which would most benefit the public.

The James River and Appomattox canals stop short of tide water. The most important of these canals is that of James River. Upon the coal mines of James

River our Atlantic sea-ports will soon become dependent for their chief supply of fuel. That dependence exists already, in respect to the fuel required for a variety of manufactures, and even the smiths within 10 miles of our sea-ports require, already, in order to carry on advantageous business, a supply of Virginia coal. There are three means (and I think only three) by which the Virginia coal can be brought to the tide. 1. By a small canal and rail roads immediately from the mines south of the river to the shipping tide water, at Ampthill, or its neighbourhood, along the valley of Falls Creek; distance, I believe, 20 miles. This is a route easily practicable, and at a moderate expense, for Falls Creek rises in the coal mines themselves. 2. By the turnpike road to Manchester, opposite Richmond. This road has been some time completed, and is of the highest utility. 3. By James River to the head of the falls, and thence by the canal to Richmond. This is, for two thirds of the coal country, the best and most obvious route. For from all the mines the coal may easily be brought to the river on rail roads, and thence boated, independently of the cheaper conveyance which Tuckahoe Creek might be made to yield to a great extent of coal land now little worked. But of what adequate use is this navigation in boats carrying, at an average, 200 bushels of coal only, when, if the canal were well constructed, 1,000 bushels might be as easily and cheaply conveyed; and when, on their arrival in Richmond they must be unloaded, again loaded into carts, and carried down, by a bad road, to the tide at Rockets, to be shipped? The Manchester turnpike, with all its expense of wagons, horses, and drivers, and the consequent waste of *labour*, *capital*, *food*, and *forage*, is a better, and I am told, as cheap a mode of conveyance.

The means by which the canal itself may be made much more useful, I will not consume your time and patience in detailing: what is most important, taking the whole subject into view, is to connect the canal, such as it is, with the tide.

In the year 1796 Mr. Weston, then engineer to the western navigation companies of the State of New-York, was called to Richmond to give his advice and opinion on this subject. It amounted to this: to connect the basin with the foot of the falls, by a succession of ten or eleven locks in one tier, carrying the race of Ross's mill upon an aqueduct across the canal, at the foot of the locks. With all deference to his talents, I cannot help remarking, that of all expensive projects of which I ever heard, this would have been one of the most useless. For, independently of the excessive inconvenience and detention which such a tier of locks at the most busy part of a navigation would occasion, the boats would arrive at their foot, in a very considerable rapid, now impracticable, and which could only be made practicable by blowing up the rocky bed of the river. When arrived there, two miles of tide water must be encountered; to navigate which these boats are wholly unfit. I cannot help thinking that the present mode of conveying the coal to Rockets is not much less eligible. I refrain from stating many other objections, which are professional, and which I believe were, as well as those already mentioned, as evident to Mr. Weston as to myself; but objections of another nature, more powerful than mere physical difficulties, opposed every project excepting that which he proposed.

In order to connect the basin of the James River canal with the tide, a very simple means is offered by the nature of the ground. To do this it will be necessary to form a capacious basin at Rockets, communicating with the tide by one or more locks. To carry a canal from thence along the level bank of James River to Shockoe Creek. A cheap aqueduct of one arch of 30 feet span will carry the work across the creek into the back street. The canal will then go up the back street, mounting by successive locks, not more than two in each tier, into the basin. The canal, from Rockets to the basin on Shockoe Hill, should be of 9 feet draft of water, and the locks 100 feet long, and 18 feet wide. This canal would, of course, bring vessels which navi-

gate our coasts and bays, and run out to the West-India Islands, into the basin on Shockoe Hill.

The legislature of the State of Virginia (for the commonwealth is deeply interested in the stock) had from time to time expressed great anxiety on the subject of completing this canal. But the dread of unforeseen difficulties and risks in carrying the work below the basin, and the value and productiveness of the stock in its present state, have hitherto overbalanced this anxiety. But considering Richmond as the principal source of fuel to the cities on our sea-coast, at least until the mines of Cape Breton shall supply us, I feel a national sentiment in deeply regretting the very fatal policy which maintains and supports the error and the mutilation of this most important work. I will not, at the same time deny, that when it is considered that those who projected and have executed the canal were men of no acquaintance either with general science, or with this particular branch of art, and knew nothing of canals but from books or hearsay, they have already done wonders. They deserve the thanks of their State, and of the Union. But the work should not stop where they have left it. Nature has perhaps done for Richmond more than for any other site where a city has been planted. For ten miles above the city, on both sides, and upon several islands of the stream there are innumerable mill-seats, supplied with water by one of the noblest rivers in the Union. Immediately above the head of the falls lies an inexhaustible treasure of coal. Every art and manufacture to which human ingenuity can employ fire and water, may be here carried on with the least expense. From above, an easy and wide-spreading navigation collects on this spot all the raw materials which our climate can produce; below, a river capable of bearing sea vessels sufficient for every trade, but that across the ocean, is ready for the exportation of its merchandise. The town itself is placed on healthy and commanding ground. But to improve these advantages to the utmost extent to which our population is equal, nothing would so much contribute as the completion of the Richmond canal.

I have dwelt specially on the coal trade to which this canal is subservient, as of first rate national importance. It is of no less importance to the State of Virginia as a means of conveyance of agricultural produce. As you will receive answers in detail to your queries relative to the amount of all the sorts of produce carried upon it, and of its actual trade, I will not add any thing further to what I have already said on the subject, but to observe, that at some distant period the Chickahominy, a river rising in the coal country and discharging itself into James River 30 miles below Richmond, where ships may take in their cargoes, offers a means of carrying down the coal destined for distant exportation.

A canal has often been projected for passing the falls of the Rappahannock at Fredericksburgh. There is no reasonable hope, however, that this work can soon be executed. The ravine of the river at the falls, on either side, is so abrupt, rocky, and irregular, that very great expense must be incurred to effect it; an expense not likely to be repaid by its trade for many years.

A canal to connect the Rappahannock with the Potomack, a few miles below Fredericksburgh, across the northern neck, has also been spoken of. It would be a highly useful work, but would require a tunnel of two or three miles. I believe it could be executed at an expense not greater than the tolls would remunerate. Such a canal, however, does not belong to the class of which I am now speaking.

The Potomack canal consists of two parts—one to pass the Great Falls, fourteen miles above Georgetown, the other to pass the Little Falls. The errors committed in the construction of the work have been enumerated above. The trade of this canal, especially during the year 1807, has been so great, that there appears every prospect of its becoming a productive work, *in those years* in which there is a considerable and equal quantity of water in the river. But upon this circumstance it must always depend. The information respecting it, which can be obtained from the company,

on the spot, renders it unnecessary for me to say more upon it.

No attempt at the improvement of the navigation of any of the rivers of Maryland between the Susquehannah and the Potomack, has been made ;-nor is there in the prospects of advantage to be derived from the navigation of the two Patuxents, the Patapsco, or the lesser rivers falling into the Chesapeake, any thing which could at present tempt capital into such undertakings.

But the Susquehannah itself has been for many years the object of almost all the attention directed in the States of Maryland, and Pennsylvania, to the improvement of our internal navigation. About six miles above Havre de Grace, this mighty river meets the tide. The place is now known by the name of Smith's Ferry. The map of the river, from thence up to Wright's Ferry, (Colun bia,) Pennsylvania, which I made in the year 1801, when directing the works carried on for the improvement of the natural bed of the river, and which by favour of the governor of Pennsylvania, I am able to exhibit with this memoir, will explain the nature of this part of the river very minutely, being drawn to a very large scale. The whole of this extent, is one tremendous rapid, which in fact continues to the north-west side of the Chickalunga Hills, three miles above Columbia. The rapid is not every where ofequal velocity, or equally dangerous. Wherever the river crosses a valley of limestone, or slate, the rocks are worn down into a smoother and wider bed ; but when it has to cross a ridge of granite its course is immediately broken by irregular masses and range of rocks ; its bed is narrow and enclosed by precipices, and its torrent furious and winding.

The Chickisalunga Falls, can be descended without danger, and no attempt to open them has been thought necessary. The ridge of granite hills, through which they break, bounds on the north-west, the beautiful Limestone Valley of Columbia, across this valley the river runs rapidly but smoothly. Another narrow ridge of granite hills, crosses the river immediately below

Columbia, over which the river falls rapidly, and then enters the wider limestone valley, known by the name of the Jochara Valley. The river spreads here to the width of three miles, its stream is gentle, though rapid, and it bounds in beautiful and fertile islands. It then suddenly contracts, and is received into the narrow ravine, which it has *sawed* down in the granite hill, called Turkey Hill. From its first entrance into the Turkey Hill, to the tide, there is no part that deserves the name of a sheet of smooth water. When the river is full, the whole ravine about half a mile in width, contains only one furious torrent, in which few rocks comparatively are to be seen above the water; but the danger is not the less, and very skilful pilots, and many, and stout hands are required to carry about or an ark safely down. But in the autumn, and in a dry season, the river itself can for six miles scarcely be seen, and its bed appears a barren and dry waste of irregular rocks, among which, the loud roaring of water is only *heard*; for, from the Turkey Hill, to near the mouth of Conestogo, the whole river is discharged through a channel generally about 60 feet wide, in the greatest part of which, the depth and the rapidity of the torrent is such, that it has not been fathomed. About a mile below the mouth of Conestogo, a narrow Limestone Valley touches the river on the north-east side, but on the west shore, not a trace of Limestone is to be seen. Four miles below Burkhalter's Ferry, the river arrives at the high range of Granite Hills, abounding in copper, in which the Gap Mine is situated; and at a place called M'Call's Ferry, it narrows to the width of 16 perches. Here I attempted to find bottom with a line of 180 feet, but failed, notwithstanding every precaution taken to procure a perpendicular descent of the weight attached to it. Through this pass, the water is rapid, but smooth and safe. The river rises here rapidly and very suddenly after the fall of rain above; and it will never be possible to erect a safe bridge at this place, so often mentioned, as the most practicable. The obstructions to navigation, by three rapids below M'Calls, is not so

considerable, as to endanger the arks and boats that descend, until they arrive at the Baldfriar Falls, below Peachbottom, and about eight miles above the tide. From M'Call's to the Slate Valley of Peachbottom, the river is filled with islands, called the Bear-Islands. Across the valley of Peachbottom, and above the Baldfriar Falls, the river is wide and safe. The best natural navigation, and that always pursued by boats descending by the natural bed of the river, is on the west side from the foot of the Bear-Islands. Above that point to Columbia, the best passage is on the east side. The most dangerous falls below Peachbottom, were Amos's and Hector's Falls, on which many wrecks occurred, until the late improvements of the navigation were made.

From this description, it may easily be imagined, that if the descent of the river with boats loaded with produce, was dangerous and difficult, the ascent was still more so. The natural obstructions were besides increased by fish dams in every part of the river, and the rival interests of the States of Pennsylvania and Maryland, prevented for many years every attempt, at artificial improvement of the bed of the river. In the mean time, each State took measures to go as far towards rendering the navigation of this river useful to their respective interests, as their means and limits would permit; and a company was incorporated in Maryland, to make a canal from the Maryland line to the tide, to pass all the obstructions in the river of the eight lowest miles: and in Pennsylvania, two companies were also incorporated; the one to connect the Susquehannah with the Schuylkill, by a navigation taken out above all the dangerous falls, and the other to connect the Schuylkill with the Delaware. The objects of none of these companies were advantageously accomplished. The Susquehannah Canal Company have, however, completed a navigable canal, liable to the objections which I have above noticed. The Pennsylvania companies have made considerable progress in the works, under the direction of a very able engineer, Mr.

Weston ; but have not completed either canal, so as to render them at all useful or productive.

At last, in the year 1801, the States of Maryland and Delaware having passed laws incorporating a company for the purpose of cutting a canal between the Chesapeake and Delaware, a former law of Pennsylvania, appropriating 10,000 dollars to the removal of obstructions in the Susquehannah, went into effect ; and the late colonel Frederick Autes, than whom no man was better fitted to accomplish its object, was charged with its execution. But he died on his arrival at the river, and the direction devolved upon me. The enclosed report to the legislature on this subject, details the extent of the work executed, and the principles on which I proceeded in the attempt to make a practicable and safe navigation both up and down the river. I will here only repeat that all my exertions were bent to force through all obstructions a channel clear of rocks, of 40 feet wide, close to the eastern shore, and never leaving any rock upon which a vessel could be wrecked, between the channel and the shore, so that in the most violent freshes a boat should always be safe by keeping close in shore.—Rocks of immense magnitude were therefore blown away in preference to following a crooked channel more cheaply made, but more difficult and dangerous, and varying in safety and practicability, according to the degree of the rise of the river. There is however one part of the navigation in which the bed of the river must for ever be pursued ; namely, from the Indian steps above M'Call's, to below the gap at M'Call's ; a part of the navigation which, if art can conquer it, must be undertaken in a state of the country infinitely more abounding in wealth and population than at present.

II. *Of the Chesapeake and Delaware Canal.*

Having now answered that part of your inquiry which relates to the general subject of canals, I come to the particular merits of the Chesapeake and Delaware ca-

nal, of which you have requested me to give special information; together with my opinion on its location, unbiassed by any interests but those of the public.

The very able report of the committee to whom your letter to the president and directors of the company was referred, and who did me the honour to confer with me on the subject, conveys to you all the information which can be given on the history of the company, their pecuniary resources and difficulties, the motives that directed their choice in the location of the work, and the system under which it was begun and pursued. Every thing also that can be collected by the most indefatigable inquiry, as to the probable proceeds of the canal, and the advantages it offers to those who have adventured in it, is also detailed; and there remains to me only the task of giving you that professional information, which as engineer to the company I have obtained, and to explain to you the means of executing it, as far as they are determined by the nature of the soil and the levels of the country.

The alluvial land lying below that part of the granite ridge which crosses the peninsula from the ferry opposite to Havre de Grace, and reaches the shores of the Delaware at Wilmington, may be considered as a regular inclined plane, sloping gradually to the south east, at the rate of about six inches in a mile. Immediately below the granite ridge, that is, along the foot of Gray's Hill, Iron Hill, and along the south bank of the Christiana Creek, which runs parallel to and close under the ridge, its highest inequalities seldom exceed 80 feet, nor does the common surface fall below 70 feet above the tide of Chesapeake at high water. This plane extends from the granite ridge to the ocean, and the only considerable depressions to be found in it, are the beds of the land drains, which are worn down into it and produce the appearance of valleys, but there are no insulated hills whatever, and the valleys are merely depressions of the ground below the plane. Hence it is evident, that by going round the heads of the water-courses, a line of canal may be found across the peninsula

between any two points on the opposite bays, in which the variation of level on the summit will be very small, and that by making the bank out of the spoils of the cut, a canal may be made at the smallest possible expense of digging and removing earth, and at no expense whatever for works of masonry, excepting at each end, where the descent requires the construction of locks. For by following the ridge dividing the waters which drain into opposite creeks, the necessity of culverts and aqueducts is wholly avoided. The soil is also of the kind most easily cut, being generally a sandy loam, on and near the surface, and beds of good clay are found in abundance for all purposes of puddling.

The advantage of so level and soft a surface for the cut is counterbalanced by the total absence of water to supply it. This circumstance is very important in determining the choice of the line of the canal, among so many that are equally practicable; for as all its water must be brought from the higher grounds upon the ridge, its location ought to be as near to the ridge as possible, in order that the feeder may be short, and the leakage and evaporation of a long feeder avoided. The location of the two ends of the canal does not however, entirely depend upon its general course along the summit; and a great variety of terminations have been proposed, as equally eligible, both on the Chesapeake and Delaware side. The former, after long and careful examination, has been decided in favour of Welsh Point, where there has, within the memory of man, been no diminution in the depth of the water, which is below the deposite of alluvium from Elk Creek, and where the water is so wide and so deep as to furnish a very capacious basin for many years to come, for the inconsiderable land wash of Back Creek and the small drains in the neighborhood. But on the Delaware side much difference of opinion has prevailed. The summit level of the canal in every case must reach the principal road leading from Christiana Bridge down the Peninsula, near a tavern called the Bear. This place is only two miles distant from Hamburgh or Red Hook, on the bay of Newcastle; and

a cheap and short cut might be made to either of these points, especially to Red Hook, did not two considerations forbid it,—the broad and wild water of the bay, and its shallowness at a great distance from the shore, there being only 4 feet 6 inches at low water. Newcastle is the next eligible point. Newcastle is situated on a prominent point, which is swept both by the flood and the ebb tide. There will, therefore, be always deep water at the *outer* wharves and piers at that place, and less than 21 feet has not been found on the outside of any of the piers lately erected; or formerly, and even at present, at the wharves, excepting only where the eddy occasioned by the piers has accumulated soft banks of mud.

There could not be a moment's hesitation in fixing the termination of the canal at Newcastle, unless the following reasons should be thought to outweigh the advantages of the best water in the Delaware, and the shortest navigation across the peninsula, which this point offers. It is, in the first place, feared, that in time of war, when the canal would be invaluable, as a means of conveyance of military stores and bodies of men, an enemy's ship of war might destroy the works at Newcastle in a sudden incursion, and return to sea, before the mischief could be prevented. It is further urged, that the mouth of the canal on the river below the tide would be liable to be filled up in a very short time, as are all places on the Delaware where there is an eddy. And it is also alleged, that Newcastle is situated so far below Philadelphia, (33 miles.) that, unless with a favourable wind, dull sailing vessels cannot reach Newcastle in one tide, when they might reach the mouth of Christiana, 4 miles higher up the river, and go up the creek with the flood.

The first argument appears to me to be deserving of consideration in a national point of view, and a small fort would be necessary to defend the mouth of the works against an enemy who should attempt to land to blow them up. But they could not be injured even by shells beyond the destruction of the gates, which a few hours could put

again in repair. To obviate the second objection it would be necessary to place the tide lock as far out as possible, and to carry out and wharf the side of the canal below the lock as far into the river as the most projected wharf. The line of the wharves is now limited to six hundred feet beyond the lowest street, called Water-street, and unless further protruded into the river by a law of the State, this distance presents no formidable difficulty to the work, and places the utmost extension of the wharves beyond the present time. The third objection is not without foundation. But the narrow and crooked navigation of Christiana Creek presents infinitely more causes of delay than the distance of four miles in the bold navigation of the Delaware. There is, however, in these objections enough to render it an object of infinite importance, both to the nation and to the company, to avail themselves of both the eastern terminations of the canal, and to make a cut also from the Bear to the Christiana Creek, about three miles above Wilmington, on a line not altogether so favourable, nor so short, as that to Newcastle, but presenting no difficulties of importance whatsoever. From the point, (Mendenhall's) at which the termination is proposed, ten feet may be carried out to the river Delaware. The objections to this termination are, the tedious and very crooked navigation of the creek for seven miles to the Delaware; the draw-bridge at Wilmington, which must be passed; but more than any other, the opposition of the tides of Delaware and Christiana Creek. For, if a boat comes into the canal at Welsh Point, at high water, and passes across in six hours, she will find half flood in Christiana, and must wait the ebb to go down. On her arrival in the Delaware in two and a half or three hours, she will have again to wait three or four hours for the flood to proceed to Philadelphia, or up the Brandywine to the celebrated mills, the interests of which are well worthy of attention. Whereas a vessel, arriving at Newcastle, and finding the flood tide running, which will always happen if she comes to Welsh Point with a flood tide, may at once proceed up the Delaware or up the Brandy-

wine or Christiana Creek, without delay. It must also be mentioned, that without a favourable tide it is difficult to work down the Christiana Creek against the wind, which is always unfavourable in some reach or other of its crooked navigation, when, on the contrary, there is ample room in the Delaware to use all advantages of wind and tide.

On the other hand it must be urged in favor of Christiana Creek, that there is navigable water for boats drawing eight feet above the proposed termination of the canal as far as Christiana Bridge, and that the navigation may be pushed still higher; that the little town of Newport is now the depot of the produce of a very extensive and fruitful country extending into Lancaster county, and is twenty miles nearer to Lancaster than Philadelphia; and that to connect so important a field of productive business immediately with the canal, it may be worth while to incur an increased expense and some inconvenience and delay in the mere *thorough fare* navigation; and it may be added, that the large fixed capital of the town of Wilmington, far exceeding that of Newcastle, demands from the good policy, as well as good will of the company or the nation, some consideration.

Well aware of the thankless task of giving a decisive and honest opinion on either side, I content myself with furnishing the materials of determination to you, and proceed to describe the nature and principles of the work actually executed in the feeder and proposed for the canal.

Between the waters of the Chesapeake and the Delaware there are three streams which, rising in the high land above the canal, may be brought down to it as feeders; the Christiana Creek, the White Clay Creek, and the Elk itself.

The Elk and the White-Clay are nearly equal in the regular quantity of water they supply; the Christiana is both smaller and more irregular. The Elk descends in a very crooked and rapid stream, eighty-four feet in four miles, from Elk Forge to the tide near Elkton, and unites with the wide waters of the Chesapeake at Turkey

Point. The ridge that separates its waters from those of the Delaware terminates in a high insulated hill, called Gray's Hill, which is united to the high land by a low and narrow ridge, crossing the post-road on the boundary line of Delaware and Maryland. The Christiana Creek is the first water falling from the high land into the Delaware. It collects all the waters that fall round the high insulated hill called Iron Hill, at the north-east foot of which it turns to the north-east, and running in that direction under the foot of the granite ridge, into the Delaware, receives the White-Clay, Red-Clay and Brandywine in its course, and also numerous land drains from the level land to the south-east. Of these three streams it has been ascertained that they may all be brought to the canal; but the Elk with the least expense and the shortest cut. The valleys in which they all run having been worn in deep and rocky land, and branching into deep ravines, the beds of rapid rivulets offer great difficulties to the work necessary to divert their course. In the Elk feeder the canal is cut in the rock: for about half a mile embankments are made across several valleys; but the principal difficulty and expense consisted in cutting through a tongue of high land called Bell-Hill, through which the digging is thirty feet for near half a mile, and again through the dividing ridge, to the depth of twenty-five feet for about half that distance; these two difficulties have been conquered. Another smaller hill remains to be cut through, but it may be avoided by a circuitous cut, much less expensive, but also much less eligible. On the Delaware side of the ridge the feeder is cut through a swampy flat of more than a mile in length, while the descent is only six inches. The general elevation of the flat is 86 feet above the tide, and as the head of the feeder at Elk Forge is only 84 feet, it could have little descent, and falls only two inches in a mile. It has on this account been made a spacious canal of three feet six inches water, twenty-two feet six inches on the surface, and twelve feet at the bottom, affording as far as it goes a good and valuable inland navigation. The feeder is six miles in length; at the end of five miles is a lock

for the passage of boats, and a side cut to communicate with the reservoir. A contiguous valley offers the means of making a reservoir of more than a hundred acres. It has been proposed to embank thirty acres for this purpose. The lock is of ten feet lift. The reservoir will be level with the upper feeder, of course ten feet above the level of the canal, and under such a head will give the canal as plenteous and rapid supply as wanted. Below the lock the feeder is five feet deep, and twenty-seven feet on the surface of the water; it will join the canal about a mile west of Aikintown. In the construction of the feeder permanence has been a very principal consideration. All the culverts are of solid masonry; no land water can run into the cut; the banks are sloped as 2 to 3; the embankments are well puddled, and the piers of the bridges are of hewn stone.

From the description which I have given of the soil of the peninsula, it is evident that the amount of digging constitutes the chief expense of the canal. To lessen this amount, and to shorten the canal, it is proposed to quit the level in three places, and to cross three land drains that lead into Christiana Creek, one at Aikintown, and two between Aikintown and the Bear. Small aqueducts and short enbankments only are necessary to effect this. If the canal should terminate at Newcastle, a narrow marsh must also be crossed; if at Christiana deeper cutting must be encountered. But neither of these difficulties increase the expense of the canal more than 7,500 dollars each, beyond that of the same length of the general cut.

On all other points the report of the committee furnishes ample information; and I will only add, that neither in Europe, nor in our own country, do I know a line of inland navigation which, by so short a distance and at so easy an expense, unites such extensive and productive ranges of commercial intercourse.

With the highest respect,

I am yours,

(Signed) B. H. LATROBE.

ALBERT GALLATIN, esq.

Secretary of the Treasury.

April 1st, 1808.

POSTSCRIPT.

In the questions proposed to me by you, the subject of artificial roads was comprehended. But being informed by you that the canal companies of Pennsylvania and Maryland had transmitted to you ample accounts of their undertakings, and as in their works, experience has taught a system and mode of execution, of the most perfect kind, I have refrained from adding any thing to the information thus acquired.—It has however occurred to me that a few remarks upon rail roads might not be unacceptable to you, especially as the public attention has been often called to this sort of improvement, and the public mind filled with very imperfect conceptions of its utility.

Rail roads may be constructed of iron, or of timber. The most durable (but also the most expensive) rail roads consists of cast iron *rails* let down on stone foundations. Such roads will last for ages. Cast iron rails secured on beds of timber are sufficiently durable for our country, and of moderate expense. Rail roads entirely of timber are fit only for temporary purposes.

A rail road consists of two pair of parallel ways, one pair for going, the other for returning carriages; single roads, with occasional passing places, are applicable to some situations, and are of course less expensive. I will concisely describe the road best adapted to the objects that in our country can be attained by it. *The rails* are of cast iron and consis of a tread and a flanch, forming in their section the letter L. The tread is three inches wide the flanch two inches high. The rails need not be more than 5-8 of an inch *average* thickness, and they may be cast in lengths of 5 to 6 feet. Each rail will, at six feet length, contain 225 cubic inches, which at four inches to the pound is 56 lb. each rail, or 1 cwt.

for every six feet in length of the road, to 44 ton per mile.

In order to form a road of these rails, they must be laid at the distance of from three and a half to five feet (according to the carriage that is to run upon them) parallel to each other; the ends of every two pair of rails being let and pinned down into a piece of timber lying across the roads. The holes for the pins must be cast in the rails. These pieces of timber may be of any form, provided they are level at the top, and they cannot be a great part of the expense of the road in any situation The most durable timber is certainly the best: but no timber can be very durable in the situation it must occupy on the surface, and partly or wholly covered with earth. The perfection of the road consists in the parallel rails being laid perfectly level with each other across the road, and perfectly jointed. In most parts of the Union the rails could, I think, be delivered at from 80 to $ 90 per ton, and in many at $ 60; but taking $ 80 as the average on the spot, the road will cost—

Rails delivered, 44 tons, at $ 80, . .	3,620
Levelling the road, very uncertain, but I will suppose as an average for levelling and filling in with good gravel or broken stone, $ 2 50 per perch, or per mile, ...	800
Timber and bedding at 50 per rail, . .	440
Incidents and superintendance, . . .	140
	5,000
For a set of returning ways, . . .	5 000
Total per mile, . . .	$ 10 000

The carriages which travel on these roads may be of various dimensions, agreeably to the material to be conveyed, and the necessary angle of the road. They have low cast iron wheels fast upon the axle, which turns round. Thus, the two wheels on the axle make the same number of revolutions in the same space of time,

the carriage necessarily goes straight forward, and cannot be thrown off the ways by any small obstruction on one side.

The principle upon which such astonishing loads may be drawn on the ways by a single horse, is the diminution of friction in the greatest possible degree. On a good rail road, descending under an angle of only one degree, one horse may draw eight tons in four wagons of two tons each, without difficulty. The astonishing loads drawn upon rail roads by single horses in England has induced many of our citizens to hope for their early application to the use of our country. I fear this hope is vain, excepting on a very small scale, and that chiefly in the coal country near Richmond. For it is evident that upon a rail road no other carriage but that which is expressly constructed for the purpose can be employed; and that to render a rail road sufficiently saving of the expense of common carriage, to justify the cost of its erection, there must be a very great demand for its use. But the sort of produce which is carried to our markets is collected from such scattered points, and comes by such a diversity of routes, that rail roads are out of the question as to the carriage of common articles. Rail roads leading from the coal mines to the margin of James River, might answer their expense, or others from the marble quarries near Philadelphia to the Schuylkill. But these are the only instances within my knowledge, in which they at present might be employed.

There is, however, a use for rail roads as a temporary means to overcome the most difficult parts of artificial navigation, and for this use they are invaluable, and in many instances offer the means of accomplishing distant lines of communication which might otherwise remain impracticable, even to our national resources for centuries to come.

Mr. Fulton's Communication.

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SIR,

By your letter of the 29th of July I am happy to find that the attention of congress is directing itself towards the opening of communications through the United States by means of roads and canals; and it would give me particular pleasure to aid you with useful information on such works, as I have long been contemplating their importance in many points of view.

But a year has not yet elapsed since I returned to America, and my private concerns have occupied so much of my time that as yet I have acquired but very little local information on the several canals which have been commenced

Such information, however, is perhaps at present not the most important branch of the subject, particularly as it can be obtained in a few months at a small expense, whenever the public mind shall be impressed with a sense of the vast advantages of a general system of cheap conveyance.

I hope, indeed, that every intelligent American will, in a few years, be fully convinced of the necessity of such works to promote the national wealth and his individual interest. Such conviction must arise from that habit of reflection which accompanies the republican principle, and points out their true interest, on subjects of political economy. From such reflections arise their love of agriculture and the useful arts, knowing them to augment the riches and happiness of the nation; hence also their dislike to standing armies and military navies as being the means of increasing the proportion of non-productive individuals whose labour is not only lost, but who must be supported out of the produce of the industrious inhabitants, and diminish their enjoyments.

Such right thinking does great honour to our nation, and leads forward to the highest possible state of civilization by directing the powers of man from useless and destructive occupations to pursuits which multiply the productions of useful labour and create abundance.

Though such principles actuate our citizens, they are not yet in every instance aware of their best interests, nor can it be expected that they should perceive at once the advantages of those plans of improvement which are still new in this country. Hence the most useful works have sometimes been opposed; and we are not without examples of men being elected into the State legislatures for the express purpose of preventing roads, canals, and bridges being constructed. But in such errors of judgment our countrymen have not been singular. When a bill was brought into the British parliament 50 years ago, to establish turnpike roads throughout the kingdom, the inhabitants for forty miles round London, petitioned against such roads. Their arguments were, that good roads would enable the farmers of the interior country to bring their produce to the London market cheaper than they who lived nearer the city and paid higher rents—that the market would be overstocked, the prices diminished, and they unable to pay their rents or obtain a living. The good sense of parliament however prevailed—the roads were made, the population and commerce of London increased, the demand for produce increased, and he who lived nearest to London still had a superior advantage in the market.

In like manner I hope the good sense of our legislature will prevail over the ignorance and prejudice which may still exist against canals. And here an important question occurs which it may be proper to examine with some attention in this early stage of our public improvements, whether, as a system, we should prefer canals to turnpike roads? Our habits are in favour of roads; and few of us have conceived any better method of opening communications to the various parts of the States. But in China and Holland canals are more nu-

merous than roads ; in those countries the inhabitants are accustomed to see all their productions carried either on natural or artificial canals ; and they would be as much at a loss to know how we, as a civilized people, could do without such means of conveyance as we are surprised at their perseverance and ingenuity in making them.* England, France, and the principal states of Europe, commenced their improvements with roads ; but as the science of the engineer improved and civilization advanced, canals were introduced, and England and France are now making every exertion to get the whole of their heavy productions water borne, for they have become sensible of the vast superiority of canals over roads.

Our system perhaps ought to embrace them both—canals for the long carriage of the whole materials of agriculture and manufactures, and roads for travelling and the more numerous communications of the country. With these two modes in contemplation, when public money is to be expended with a view to the greatest good, we should now consider which object is entitled to our first attention. Shall we begin with canals, which will carry the farmer's produce cheap to market and return him merchandise at reduced prices ? or shall we first make roads to accommodate travellers and let the produce of our farms, mines and forests, labour under such heavy expenses that they cannot come to market ?

To throw some light on this interesting question, I will base my calculations on the Lancaster turnpike road. There the fair experiment has been made to penetrate from Philadelphia to the interior country, and the mode of calculation here given will serve for drawing comparisons on the utility of roads and canals for all the great leading communications of America.

From Philadelphia to the Susquehannah, at Columbia is 74 miles. That road, if I am rightly informed,

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* The royal canal from Canton to Pekin is 825 miles long, its breadth 50 feet, its depth 9 feet.

cost on an average 6,000 dollars a mile, or 444,000 dollars for the whole. On it, from Columbia to Philadelphia, a barrel of flour, say 200 weight, pays one dollar carriage. A broad wheeled wagon carries 30 barrels or 3 tons, and pays for turnpike 3 dollars. Thus for each ton carried, the turnpike company receives only one dollar.

I will now suppose a canal to have been cut from Philadelphia to Columbia, and with its windings to make 100 miles, at 15,000* dollars a mile, or for the whole, 1,500,000 dollars. On such canal, one man, one boy, and horse, would convey 25 tons 20 miles a day,† on which the following would be the expenses :

One man, - - - - -	$ 1 00
One horse, - - - - -	1 00
One boy, - - - - -	0 50
Tolls for repairing the canal, - -	1 00
Tolls for passing locks, inclined planes, tunnels, and aqueducts, - -	1 00
Interest on the wear of the boat, -	0 50
Total,	$ 5 00

This is equal to 20 cents a ton for 20 miles, and no more than one dollar a ton for 100 miles, instead of 10 dollars paid by the road. Consequently, for each ton carried from Columbia to Philadelphia, on the canal, the company might take a toll of six dollars instead of one, which is now got by the road ; and then the flour would arrive at Philadelphia for 7 dollars a ton, instead of ten, which it now pays. The merchandise would also arrive at Columbia from Philadelphia, for 3 dollars a

* On averaging the canals of America, 15,000 dollars a mile will be abundantly sufficient to construct them in the best manner, particularly if made on the inclined-plane principle, with small boats, each carrying 6 tons.

† One horse will draw on a canal from 25 to 50 tons, 20 miles in one day. I have stated the least they ever do, and the highest rate of charges, that no deception may enter into these calculations.

ton less than is now paid, which cheap carriage both ways would not only benefit the farmer and merchant, but would draw more commerce on the canal than now moves on the road, and thereby add to the profits of the company.

But to proceed with my calculations, I will suppose that exactly the same number of tons would move on the canal that are now transported by the road. Again, let it be supposed that at one dollar a ton the turnpike company gains five per cent. per annum on their capital of 444,000 dollars, or 22,200 dollars, consequently 22,200 tons must be carried, which at six dollars a ton to the canal company would have given 133,200 dollars a year, or eight and a half per cent. for their capital of 1,500,000 dollars.

The reason of this vast difference in the expense of carriage by roads or canals will be obvious to any one who will take the trouble to reflect, that on a road of the best kind four horses, and sometimes five, are necessary to transport only three tons. On a canal one horse will draw 25 tons, and thus perform the work of 40 horses; the saving, therefore, is in the value of the horses, their feeding, shoeing, geer, wagons, and attendance. These facts should induce companies to consider well their interest when contemplating an enterprise of this sort; and what would be their profits not only in interest for their capital, but the benefit which their lands would receive by the cheap carriage of manure and of their productions.

In considering the profits to accrue to a company from a canal instead of roads there is another important calculation to be made, and for that purpose I will proceed with the Lancaster Turnpike: supposing it to extend to Pittsburgh, 320 miles, on which, the carriage being at the rate now paid from Columbia to Philadelphia, (that is, 10 dollars a ton for 74 miles,) the ton from Pittsburgh would amount to 42 dollars; at which price a barrel of flour would cost four dollars in carriage, an expense which excludes it from market. Thus grain, the most important and abundant produc-

tion of our interior country, and which should give vigour to our manufactures, is shut up in the districts most favourable to its culture; or to render it portable and convert it into cash, it must be distilled, to brutalize and poison society. In like manner all heavy articles of little moneyed value can only move within the narrow limits of 100 miles; but were a canal made the whole distance, and by one or more companies they might arrange the tolls in the following manner, so as to favour the long carriage of heavy articles:

The expense of man, boy, and horse, as before stated, would cost only three dollars to boat one ton of flour 300 miles. This is 30 cents a barrel; suppose then that the company received 70 cents a barrel, or seven dollars a ton, flour could then come from Pittsburgh to Philadelphia for one dollar a barrel, the sum which is now paid from Columbia; thus the canal company would gain seven dollars a ton by a trade which could never move through a road of equal length. Here we see that on canals the tolls may be arranged so as to draw to them articles of little moneyed value; and it would be the interest of the company or companies to make such regulations. But on turnpike roads no such accommodation of charges in proportion to distance can be effected, because of the number of horses which cannot be dispensed with.* Even were the roads made at the public expense and toll free, still the carriage of one ton for 300 miles would cost at least 35 dollars. But were canals made at the public expense, and no other toll demanded than should be sufficient to keep them in repair, a ton in boating and tolls would only cost three dollars for 300 miles; and for 35 dollars, the sum which must be paid to carry one ton 300 miles on the best of roads, it could be boated *three thousand five*

* In my work on small canals, published in 1796. page 140, there is a table showing a mode of regulating the boating and tonnage, in such a manner that a ton may be transported one thousand three hundred miles for five dollars; yet by this method canal companies would gain more toll than by any other means yet practised.

hundred miles, and draw resources from the centre of this vast continent.

But striking as this comparison is, I will still extend it. The merchandise which can bear the expense of carriage on our present roads to Pittsburgh, Kentucky, Tennessee, or any other distance of 300 miles, and which, for that distance, pays 100 dollars a ton, could be boated on canals *ten thousand miles for that sum*.

As these calculations are founded on facts which will not be denied by any one acquainted with the advantages of canals, it is the interest of every man of landed property, and particularly of the farmers of the back countries, that canals should be immediately constructed, and rendered as numerous as the funds of the nation will permit, and the present population requires; and as inhabitants multiply most towards the interior, and must extend westward, still moving more distant from the sea-coast and the market for their produce, it is good policy, and right that canals should follow them. In 25 years our population will amount to 14 millions; two thirds of whom will spread over the western countries. Suppose then that 3,500 000 dollars were annually appropriated to canals, such a sum would pay for 300 miles of canal each year, and in 20 years we should have 6.000 miles circulating through and penetrating into the interior of the different States; such sums, though seemingly large, and such works, though apparently stupendous, are not more than sufficient to keep pace with the rapid increase of our population, to open a market and carry to every district such foreign articles as we near the coast enjoy. With this view of the subject, arises a political question of the utmost magnitude to these States—which is:

That as our national debt diminishes, and the treasury increases in surpluss revenue, will it not be the best interest of the people to continue the present duties on imports, and expend the products in national improvements?

To illustrate this question, I will state some examples of the rate of duties and the expense of carriage to

prove that by keeping on the duties, and making canals with the revenue, goods, in a great number of instances, will be cheaper to the consumer, than by taking off the duties, and leaving the transport to roads.

First Example.

Brown sugar pays in duty 2 1-2 cents a pound, or for 100 pounds, - - - - - -	$2 50
It pays for wagoning 300 miles, - -	5 00
Total,	$7 50

By the canal it would cost in boating 15 cents for 300 miles, consequently the boating and duty would amount to $2 65, therefore by keeping on the duty, and making the canals, sugar would arrive at the interior, 300 miles, for $2 35 the hundred weight cheaper than if the duties were taken off and the transport left to roads.

Second Example.

One bushel of salt, weighing 56 pounds, paid in duty, - - - - - - -	$0 20
To carry it 300 miles, by roads, the expense is, - - - - - - -	2 50
Total,	$2 70

By the canal it would cost for boating 300 miles, 7 1-2 cents. By keeping on the duties and making the canals, it would arrive to the interior consumer $2 32 1-2 cents the bushel cheaper than were the duties taken off and the transport left to roads.

Third Example.

Molasses pays 5 cents a gallon duty; this is for 100 pounds, ...	$ 0 75
It pays for wagoning 300 miles, . .	5 00
Total,	$ 5 75

By the canal the carriage would cost 15 cents, and it would arrive at the interior at $ 4 10 cents the hundred weight or 27 cents a gallon cheaper than were the duties taken off and the transport left to roads.

Numerous other articles might be stated to show that the real mode of rendering them cheap to the interior consumer, is to keep on the duties and facilitate the carriage with the funds so raised. These however may be considered as partial benefits, and not sufficiently general to warrant keeping on the duties. But there is a point of view in which I hope it will appear that the advantages are general, and will be felt throughout every part of the States. It is by reducing the expense of all kinds of carriage, and thus economize to each individual more than he now pays in duty on the foreign articles he consumes.

For Example.

Wood for fuel is an article of the first necessity. It cannot bear the expense of transport 20 miles on roads. At that distance it is shut out from the market, and the price of fuel is consequently raised to the amount of the carriage. Were a cord of wood carried 20 miles on roads, it would pay for wagoning at least 3 dollars On a canal it would pay 20 cents. Thus on only one cord of wood there is an economy of $ 2 80 cents. Which economy would pay the duty

On 14 lbs of tea, at 20 cents the lb duty, or
140 lbs. of sugar, at 2 cents the lb duty, or
56 lbs. of coffee, at 5 cents the lb duty, or
14 bushels of salt, at 20 cts the bushel duty. or
56 gallons of molasses, at 5 cents the gallon duty.

I will now suppose a city of 50 000 inhabitants, who, for their household and other uses, will consume 50 000 cords a year, on which there would be an economy of $ 140 000, a sum in all probability equal to the duties paid by the inhabitants; for the duties divided on the whole of the American people are but $2 28 cents to each individual Here I have estimated each person to pay $ 2 80 cents, yet this estimate is made on one cord

of wood to each inhabitant of a city. Were I to calculate the economy on the carriage of building timber, lime, sand, bricks, stone, iron, flour, corn, provisions, and materials of all kinds which enter or go out of a city, it would be five times this sum; and thus the towns and cities are to be benefitted. The farmer or miller who lives 20 miles from a market, pays at least 22 cents to wagon a barrel of flour that distance. By the canal it would cost two cents: the economy would be 20 cts.; at 100 miles the economy would be 100 cents, and at 150 miles it would be 150 cents. Beyond this distance flour cannot come to market by roads, yet at this distance the economy of 150 cents in the carriage of one barrel of flour would pay the duty on

7 1-2 pounds of tea;
or 75 pounds of sugar;
or 30 pounds of coffee;
or 7 1-2 bushels of salt;
or 30 gallons of molasses.

Thus it is that the benefits arising from a good system of canals are general and mutual. Therefore should peace, and the reduction of the national debt, give an overflowing treasury, I hope you, and the majority of Americans, will think with me, that the duties should not be taken off nor diminished; for such an act, instead of relieving the people, would really oppress them, by destroying the means of reducing the expense of transports, and of opening to them a cheap mode of arriving at good markets.

To proceed with these demonstrations, let us look at the rich productions of our interior country:

Wheat, flour, oats, barley, beans, grain, and pulse of every description;
Cider, apples, and fruits of all kinds;
Salt, salted beef, pork, and other meats;*

* Animals are now driven to market 300 or more miles at a considerable expense and loss of flesh, for two principal reasons; first, the expense of transporting the salt to the interior, and second, the expense of carrying the salted meats to market.

Hides, tallow, bees-wax;
Cast and forged iron;
Pot and pearl ashes, tanner's bark;
Tar, pitch, rosin, and turpentine;
Hemp, flax, and wool;
Plaster of Paris, so necessary to our agriculture;
Coals and potter's earth for our manufactures;
Marble, lime, and timber for our buildings.

All of these articles are of the first necessity, but few of them can bear the expense of 5 dollars the hundred weight to be transported 300 miles on roads. Yet on canals they would cost, in boating, only 15 cents the 100 weight for that distance.

There is another great advantage to individuals and the nation arising from canals, which roads can never give. It is that when a canal runs through a long line of mountainous country, such as the greater part of the interior of America, all the grounds below, for half a mile or more, may be watered and converted into meadow and other profitable culture. How much these conveniences of irrigation will add to the produce of agriculture, and the beauties of nature, I leave to experienced farmers and agricultural societies to calculate.

In Italy and Spain it is the practice to sell water out of the canals, for watering meadows and other lands. In such cases tubes are put into the canal, under the pressure of a certain head of water, and suffered to run a given time for a fixed price; the moneys thus gained added much to the emoluments of the canal companies.

But with all these immense advantages which canals give, it may be a question with many individuals, whether they can be constructed in great leading lines from our sea-coast and navigable rivers to the frontiers of the several states, or pass our mountains and penetrate to the remotest parts of our interior country. Should doubts arise on this part of the plan, I beg leave to assure you, that there is no difficulty in carrying canals over our highest mountains, and even where nature has denied us water. For water is always to be found in the valleys; and the canal can be constructed to the foot

of the mountain, carrying the water to that situation.—Should there be no water on the mountain or its sides, there will be wood or coals ; either or both of which can be brought cheap to the works by means of the canal. Then with steam engines the upper ponds of canal can be filled from the lower levels, and with the engines the boats can, on inclined planes, be drawn from the lower to the upper canal. For this mode of operating it is necessary to have small boats of six tons each. As the steam engines are to draw up and let down the boats on inclined planes, no water is drawn from the upper level of canal, as when locks are used. Consequently, when the upper ponds have been once filled, it is only necessary that the engine should supply leakage and evaporation. There is another mode of supplying the leakage and evaporation of the higher levels : On the tops and sides of mountains there are hollows or ravines which can be banked at the lower extremity, thus forming a reservoir to catch the rain or melted snow.—From such reservoirs the ponds of canal can be replenished in the dry months of summer. This mode of reserving water is in practice in England for canals, and in Spain for irrigation. In this manner I will suppose it necessary to pass a mountain 800 feet high ; then four inclined planes, each of 200 feet rise, would gain the summit, and four would descend on the other side—total, 8 inclined planes, and 8 steam engines. Each steam engine of 12 horse power would cost about ten thousand dollars, in all 80,000 dollars ; each would burn about 12 bushels of coal in 12 hours, or 96 bushels for the 8 engines for one day's work.

The coals in such situations may be estimated at 12 cts. a bushel, or - - - - - -	$ 11 52
At each engine and inclined plane there must be 5 men—total, 40 men, at one dollar each,	40 00
Total,	$ 51 52

For this sum they could pass 500 tons in one day over

the 8 inclined planes, which for each ton is only -
- - - - - - - - 10 cents.
Suppose the mountain to be 20 miles wide, boating for each ton would cost 20

Total, 30 cents

a ton for passing over the mountain, which will be more or less, according to circumstances. These calculations being only intended to remove any doubts which may arise on the practicability of passing our mountains.

Having thus in some degree considered the advantages which canals will produce in point of wealth to individuals and the nation, I will now consider their importance to the Union, and their political consequences.

First, their effect on raising the value of the public lands, and thereby augmenting the revenue.

In all cases where canals shall pass through the lands of the United States, and open a cheap communication to a good market, such lands will rise in value for 20 miles on each side of the canal. The farmer who will reside 20 miles from the canal can in one day carry a load of produce to its borders; and where he lands 600 miles from one of our seaport towns his barrel of flour, in weight 200 lb., could be carried that distance for 60 cents, the price which is now paid to carry a barrel 50 miles on the Lancaster turnpike. Consequently, as relates to cheapness of carriage and easy access to market, the new lands which lie 600 miles from the seaports would be of equal value with lands of equal fertility which are 50 miles from the sea-ports. But not to insist on their being of so great a value until population is as great, it is evident that they must rise in value in a three or four fold degree. Every lineal mile of canal would accommodate 25,600 acres. The land sold by the United States in 1806, averaged about 2 dollars an acre, and certainly every acre accommodated with a canal would produce 6 dollars; thus only 20 miles of canal each year running through national lands would raise the value of 512,000 acres at least 4 dollars an

acre, giving 2,048,000 dollars to the treasury; a sum sufficient to make 136 miles of canal. Had an individual such a property and funds to construct canals to its centre, he certainly would do it for his own interest. The nation has the property, and the nation possesses ample funds for such undertakings.

Secondly, on their effect in cementing the Union and extending the principles of confederated republican government. Numerous have been the speculations on the duration of our Union, and intrigues have been practised to sever the western from the eastern States. The opinion endeavoured to be inculcated was that the inhabitants behind the mountains were cut off from the market of the Atlantic States; that consequently they had a separate interest, and should use their resources to open a communication to a market of their own; that remote from the seat of government, they could not enjoy their portion of advantages arising from the Union, and that sooner or later they must separate and govern for themselves.

Others, by drawing their examples from European governments, and the monarchies which have grown out of the feudal habits of nations of warriors, whose minds were bent to the absolute power of the few, and the servile obedience of the many, have conceived these States of too great an extent to continue united under a republican form of government, and that the time is not distant when they will divide into little kingdoms, retrograding from common sense to ignorance, adopting all the follies and barbarities which are every day practised in the kingdoms and petty states of Europe. But those who have reasoned in this way have not reflected that men are the creatures of habit, and that their habits as well as their interests may be so combined as to make it impossible to separate them without falling back into a state of barbarism. Although, in ancient times, some specks of civilization have been effaced by hordes of uncultivated men, yet it is remarkable that since the invention of printing and the general diffusion of knowledge no nation has retrograded in

science or improvements; nor is it reasonable to suppose that the Americans, who have as much if not more information in general than any other people, will ever abandon an advantage which they have once gained. England, which at one time was seven petty kingdoms, has by habit, long been united into one. Scotland, by succession, became united to England, and is now bound to her by habit, by turnpike roads, canals, and reciprocal interests. In like manner all the counties of England, or departments of France, are bound to each other; and when the United States shall be bound together by canals, by cheap and easy access to market in all directions, by a sense of mutual interests arising from mutual intercourse and mingled commerce, it will be no more possible to split them into independent and separate governments, each lining its frontiers with fortifications and troops, to shackle their own exports and imports to and from the neighboring States, than it is now possible for the government of England to divide and form again into seven kingdoms.

But it is necessary to bind the States together by the people's interests, one of which is to enable every man to sell the produce of his labor at the best market and purchase at the cheapest. This accords with the idea of Hume, "That the government of a wise people would be little more than a system of civil police; for the best interest of man is industry, and a free exchange of the produce of his labor for the things which he may require."

On this humane principle, what stronger bonds of union can be invented than those which enable each individual to transport the produce of his industry 1,200 miles for 60 cents the hundred weight? Here then is a certain method of securing the union of the States, and of rendering it as lasting as the continent we inhabit.

It is now eleven years that I have had this plan in contemplation for the good of our country. At the conclusion of my work on small canals there is a letter to Thomas Mifflin, then governor of the State of Pennsylvania, on a system of canals for America. In it I con-

templated the time when "*canals should pass through every vale, wind round each hill, and bind the whole country together in the bonds of social intercourse;*" and I am now happy to find, that, through the good management of a wise administration, a period has arrived when an overflowing treasury exhibits abundant resources and points the mind to works of such immense importance. Hoping speedily to see them become favorite objects with the whole American people.

I have the honor to be,
Your most obedient,
ROB'T FULTON.

To Albert Gallatin, Esq.
Secretary of the Treasury.

Washington, December the 8th, 1807.